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Leyre REY GUEMBE

UNAVOIDABLE ASPECTS TO PROMOTE DEEPER LEARNING IN SCIENCE: Proposal implementation in the UK

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Facultad de Ciencias Humanas y Sociales
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Grado en Maestro de Educación Primaria /
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Preámbulo

El Real Decreto 1393/2007, de 29 de octubre, modificado por el Real Decreto 861/2010, establece en el Capítulo III, dedicado a las enseñanzas oficiales de Grado, que “estas enseñanzas concluirán con la elaboración y defensa de un Trabajo Fin de Grado […] El Trabajo Fin de Grado tendrá entre 6 y 30 créditos, deberá realizarse en la fase final del plan de estudios y estar orientado a la evaluación de competencias asociadas al título”.

El Grado en Maestro en Educación Primaria por la Universidad Pública de Navarra tiene una extensión de 12 ECTS, según la memoria del título verificada por la ANECA. El título está regido por la *Orden ECI/3857/2007, de 27 de diciembre, por la que se establecen los requisitos para la verificación de los títulos universitarios oficiales que habiliten para el ejercicio de la profesión de Maestro en Educación Primaria*; con la aplicación, con carácter subsidiario, del reglamento de Trabajos Fin de Grado, aprobado por el Consejo de Gobierno de la Universidad el 12 de marzo de 2013.

Todos los planes de estudios de Maestro en Educación Primaria se estructuran, según la Orden ECI/3857/2007, en tres grandes módulos: uno, *de formación básica*, donde se desarrollan los contenidos socio-psico-pedagógicos; otro, *didáctico y disciplinar*, que recoge los contenidos de las disciplinares y su didáctica; y, por último, *Practicum*, donde se describen las competencias que tendrán que adquirir los estudiantes del Grado en las prácticas escolares. En este último módulo, se enmarca el Trabajo Fin de Grado, que debe reflejar la formación adquirida a lo largo de todas las enseñanzas. Finalmente, dado que la Orden ECI/3857/2007 no concreta la distribución de los 240 ECTS necesarios para la obtención del Grado, las universidades tienen la facultad de determinar un número de créditos, estableciendo, en general, asignaturas de carácter optativo.

Así, en cumplimiento de la Orden ECI/3857/2007, es requisito necesario que en el Trabajo Fin de Grado el estudiante demuestre competencias relativas a los módulos de formación básica, didáctico-disciplinar y practicum, exigidas para todos los títulos universitarios oficiales que habiliten para el ejercicio de la profesión de Maestro en Educación Primaria.

En este trabajo, el módulo *de formación básica* nos ha permitido desarrollar la capacidad de reunir e interpretar datos relevantes para analizar y reflexionar sobre temas relevantes metodológicos y prácticas de aula para así poder investigar, innovar y mejorar la labor docente, lo que se concreta en la propuesta metodológica constructivista, la cual es testada y analizada. Además, nos permite enmarcar la propuesta didáctica teniendo en cuenta la política educativa internacional ya se implementa en Reino Unido, los componentes organizativos de los centros, así como el desarrollo evolutivo, aspectos psicológicos y sociales del alumnado con el que se lleva a cabo. Destacar también el uso de las nuevas tecnologías para la búsqueda bibliográfica y para el producto final de la propuesta didáctica.

El módulo *didáctico y disciplinar* correspondiente al área de ciencias experimentales se concreta en el marco metodológico y conceptual en el que se refleja el conocimiento científico, de cada una de las unidades planteadas, para poder ser empleado con fines didácticos. Específicamente, en el planteamiento de tres unidades en relación a la estructura y locomoción de los animales, y en el completo desarrollo de una de ellas dirigida a la estructura del cuerpo humano.

Asimismo, el módulo *practicum* nos ha permitido la observación en el aula y el análisis de los aspectos y principios metodológicos propuestos para alcanzar el conocimiento científico. Destacar su desarrollo en el *practicum III*, concretamente en el colegio de educación primaria *The Mount, St.Mary Preparatory School* en *Liverpool (Reino Unido).*

Por último, el módulo *optativo* de mención en Lengua extranjera, Inglés, se manifiesta en la competencia lingüística reflejada en la redacción de las secciones: *introduction, objectives, theoretical framework*, *science-in-action proposal* and *implementation of lesson 2 in the United Kingdom* del índice.

Por otro lado, la Orden ECI/3857/2007 establece que al finalizar el Grado, los estudiantes deben haber adquirido el nivel C1 en lengua castellana. Por ello, para demostrar esta competencia lingüística, se redactan también en esta lengua los apartados “discusión” y “conclusiones”, así como el preceptivo resumen que aparece en el siguiente apartado.

Resumen

Las propuestas constructivistas parecen contribuir a alcanzar el conocimiento científico y, sin embargo, no abundan en educación. Este trabajo tiene como objetivo definir los aspectos esenciales, y sus principios correspondientes, para diseñar propuestas constructivistas que permitan el aprendizaje científico profundo. Se definen tres aspectos: aprender haciendo, ambientes sociales y facilitación. Se plantean tres bloques de contenido relacionados con la estructura y locomoción animal, y se desarrolla el segundo, que consiste en construir una estructura con cartón, cintas elásticas e hilo como representación de huesos, músculos y tendones/ligamentos. Tras poner en práctica este segundo bloque con el alumnado de Year 3 del colegio The Mount, Reino Unido, los principios establecidos se manifiestan con éxito, aunque algunos son limitados por edad, tiempo, horario, currículo, competitividad o espacio. Indudablemente, este marco metodológico contribuye a que el aprendizaje científico sea profundo. El sistema educativo debe facilitar su implementación y aceptar el reto que supone.

Palabras clave: constructivismo; aprendizaje profundo; aprender haciendo; ambientes sociales; facilitación.

Abstract

Constructivist approaches are believed to contribute to scientific knowledge acquisition, but they are not currently implemented in schools. This present work establishes three unavoidable aspects, and their pertinent principles, to be considered when designing a proposal aimed to reach deeper learning in science. These three aspects are: learning by doing, social environment and facilitation. Therefrom, three lessons are proposed in relation to the structure and locomotion of animals. Lesson 2 is deeply developed and focuses on creating a structure made out of carton, elastic bands and thread to represent bones, muscles and tendons/ligaments. After its implementation in Year 3 at The Mount in the United Kingdom, every principle succeeds unless some are limited by age, schedule, curriculum, competitiveness or physical space. In the end, the approach certainly contributes to deeply learn science suggesting that it is time for education to make it feasible and dare to take the challenge.

Keywords: constructivism; deeper learning; learning by doing; social environments; facilitation.

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INTRODUCTION

Education urgently needs a change. The vast majority of educators continue developing traditional practices in most of schools. According to Tobin (1993) problems regarding these practices exist regardless of those who analyse them. So then, why do some professionals currently still resisting to change their methodological approach when teaching after so many years?

Although Tobin continue pointing out that there has always been a resistance to change, the American Association for the Advancement of Science (1991) states that there is a *"widespread acceptance"* of different pedagogies, including constructivism, which are alternatives to traditional practices and can make a remarkable change in science education (Matthews, 1998; Tobin, 1993). As a matter of fact, these authors mentioned constructivist approaches many years ago, but constructivist approaches still being considered innovative. Could it be due to their difficulty to implement? On the one hand, areas of knowledge can be taught through master lectures in which teachers give specific input to students and they have to understand or memorize it in order to carry out an activity, as for example, a theoretical explanation about the osmosis principle when equalizing concentrations separated by a semipermeable membrane. Once learners are given the scientific concept, they memorize and/or test it. On the other hand, the same knowledge can be reached without directly providing this input but designing an activity which enables them to figure the osmosis principle out on their own. As a consequence, teachers need to provide learners with tools and materials to explore and test in order to acquire scientific knowledge from their personal experience. In our case pupils could experience osmosis principle having materials such as water, salt, filter paper and containers at their disposal. This second option appears much more challenging from a didactic point of view. It requires teachers to be capable of dealing with unforeseen difficulties that may come up during the learning process of students, and it also requires a much deeper knowledge of the content and, what is more, pedagogical knowledge (Cochran, 1997). This means, professionals able to facilitate knowledge without directly providing it and offering a unique pathway to come to a conclusion. The latter case is where the nature of constructivism is regarded.

Accordingly, this work is based on a constructivist approach so that it is necessary to have a full understanding of what constructivism implies. Concretely, It is important to clearly specify which aspects of different schools of thought are going to be taken into account when developing the proposal. First of all, I examine the main features of Piaget's constructivism, Papert's constructionism and Vygotsky's socio-constructivist approach which are necessary to understand and support the s*cience-in-action* proposal. Second of all, I concrete the consequences of constructivism in the science class by specifying three aspects, *learning by doing, social environment* and *facilitation,* and their principles which I believe to be unavoidable for reaching the four aspect, *deeper learning*. I explain previous experiences that show the effectiveness of this approach. Moreover, I propose three lessons on the same topic (structure and locomotion of animals) at different levels of detail based on this methodology in order to test the design of the three aspects when contributing to deeply learn scientific knowledge. I develop and implement lesson 2 at The Mount, St.Mary's Preparatory School, Liverpool (UK), and I analyse the results according to concrete indicators and descriptors established for each principle of the aspects considered essential in the methodological framework. To conclude, evidences suggest that the approach is potentially powerful for the science class but some limitations should be faced to make its implementation feasible.

1. OBJECTIVES

This present work's *general objective* is:

- To establish and define the aspects required to design a proposal based on a methodological approach aimed to reach deeper learning and to test its effectiveness when deeply learn science, more specifically, the structure and locomotion of animals.

The s*pecific objectives* are:

- To establish the aspects required in constructivist approaches to promote deeper learning of scientific knowledge.
- To specify the principles for each aspect to contribute to reach deeper learning in science.
- To design a didactic proposal in relation to the structure and locomotion of animals which reflects the aspects, and their pertinent principles, previously considered unavoidable to foster deeper learning in science.
- To analyse the effectiveness of each aspect, and its principles, when contributing to deeper learning in science in the implementation of *Lesson 2* related to the human body structure.
- To evaluate the strengths and limitations when implementing a proposal based on a constructivist approach that takes into account the aspects and principles previously defined to be unavoidable to design a proposal which enables learners to deeply learn science.

2. THEORETICAL FRAMEWORK

2.1. Constructivist approaches

Whereas the word “constructivism” is widely used in pedagogy, not everybody is aware of its implication in education. Ackermann (2004) examines the differences between Piaget´s constructivism, Papert´s constructionism and Vygotsky´s socio-constructivist approaches and points out that the three of them have something in common: knowledge is actively constructed by people and individuals learn through their own experience by acting in the world. In the same direction, Von Gasersfeld (1992) claims that it is necessary to relate knowledge and reality as knowledge cannot be independent from the world (Tobin & Tippins, 1993). Thus, the interaction of an individual with the real world and, consequently, the manipulation of external objects is, apparently, the way humans construct knowledge and the world (Ackermann, 2004).

The following subsubsections develop the main features of these three approaches (Ackermann, 2004).

2.1.1. Piaget constructivism

Piaget is known for his constructivist theory of cognitive development. He establishes several stages related to the cognitive development of children and states which are the capacities and interests of a child at each stage. For him, learning occurs through experience and rational thinking.

There are three implications of Piaget´s theory for education which are worth mentioning: *teaching can´t be direct*, the interpretation of knowledge and experience needs to take place; *knowledge is not information*, experience plays a vital role to construct knowledge; and *a theory of learning that ignores resistances to learning misses the point*, previous ideas cannot be ignored so that teachers need to work on building knowledge from them (Ackermann, 2004).

2.1.3. Papert's constructionism

I refer to Papert´s constructionism when he focus on *"learning through making",* or discovery learning (Bruner, 1960). Again manipulating, exploring and experiencing are essential in the learning process. This is especially important when it comes to accommodate, develop and boost previous ideas or *"views of the world"* (Ackermann, 2004). If we want learners to retain something to be applied and used for a long period of time, they need to experience and practice it. Otherwise, they will forget it (Matthews, 1998).

Regarding *learning through making*, Papert, along with Vygotsky, focuses on external support or *artifacts* to represent the ideas of an individual and to develop their understanding to a higher level, or *models* (Gilbert, 2004) to simplify complex and abstract concepts, develop understanding and foster authentic science education.

2.1.4. Vygotsky's socio-constructivism

Vygotsky's socio-constructivism is based on the idea of community, on the necessity of social interaction for constructing knowledge.

During the learning process, pupils will have to rebuild their initial hypothesis and deal with huge variety of difficulties. Educators need to provide learners with opportunities to promote learning which must allow them to learn from experience and interact with the world. These opportunities should be considered a means to rebuild previous knowledge and deeply learn.

But, the construction of knowledge is not just an individual process, it needs to take collaboration and interaction into account as it involves communication and socialization. Tobin and Tippins (1998) explain that scientific knowledge has been constructed over time not only because of scientific discoveries but also due to social negotiations and agreements. This implies that knowledge, experience, negotiations and consensus cannot be separated. So, it appears that if knowledge is constructed in social environments, kept it in one's mind and applied in real situations, deeper learning takes place. From a constructivist point of view, knowledge is not simply something to be *“transmited-delivered at one end, encoded, retained, and re-applied at the other”* but it is *“an experience to be actively built, both individually and collectively”* (Ackermann, 2004, p.16).

In the following subsection I develop the consequences of constructivism in the science class which are reflected in the science-in-action proposal (section 3).

2.2. Consequences of constructivism in the science class

In this subsection I am going to specify essential aspects which should be considered to design a constructivist proposal which enables deeper learning of scientific knowledge: learning by doing, social environment, and facilitation. I want students *“actively engaged, developing intentionality, generating new ideas, and building solidarity and shared commitment to a practice of design, experimentation, and tinkering”* (Petrich, Wilkinson & Bevan, 2013, p.52). My global aim is to design the experience for learners to create, generate, share and discuss new ideas, participate, confront and solve *“conceptual challenges”* (Petrich et al., 2013). An unavoidable requisite is to provide them with opportunities which allow active participation, development of an idea or plan, thinking of new strategies and sharing and working collaboratively. In the practice, this means inclusive social environment, learning by doing and facilitation. Principles for each of these aspects as well as deeper learning are widely developed in the following subsubsections.

2.2.1. Learning by doing

My proposal for learning science in class is an inquiry-based approach that can be defined as the *“learner-driven construction and deconstruction of objects or installations”* (Gutwill, Hido & Sindorf, 2015, p.3). Activities and tasks are designed to encourage students to create and experience in order to fulfil specific tasks which drive them to the final production. This directly requires the understanding and development of scientific concepts and phenomena (Petrich et al., 2013).

It is not about designing an specific scenario where students need to discover something that has been previously done by the teacher and it is the teacher the one who guide the whole process in order to direct students to reach the correct (and closed) solution, answer or rule. This could lead to a close process where students perform what it is said by the teacher, and it could also mean that they are not reflecting about their actions. Reflexion and opportunities for self-direct learning are crucial for deeper learning to happen. On the contrary, learners could be simply following instructions to reach a final common aim that has been previously established. Thus, educators have to create opportunities for learners to be completely involved and self-direct their learning process as to find their own pathways to reach goals. Directing students through the same fixed path should be avoided (Tseng, Liang & Tsai, 2014).

Students construct personal knowledge through experience (Ackermann, 2013; Bruner, 1960) based on manipulation, creation and problem-solving situations. Special interest is placed on the learners authorship when it comes to overcome difficulties while they are experiencing. They have to manipulate and test the functionality of several materials at their disposal as well as they have to try divers forms. They can test and make changes as many times as they need.

Adversities encountered by the learners are considered challenges. It is the best way for deeper learning to occur.

Moreover, creativity plays a vital role. Our society needs people willing to design and create new gadgets, theories, methodologies. People ready to change. People able to innovate and propose several solutions to tackle a problem or face an unexpected situation. Learners re-invent and try to use their knowledge in order to construct a valid model. During the process they come up with unexpected problems and discoveries which make them think of different ways of overcoming the difficulties and, consequently, they update their previous knowledge and develop their capacities (Ackermann, 2013).

All in all, we can concrete *five principles* when *designing an activity* that let the learners discover for themselves (Petrich et al., 2013):

- *Activities and investigation build on learners´ prior interests and knowledge*.

Activities are design to meet learners previous knowledge and interest. I take advantage of materials already known by the learners. They have to manipulate and use them in unknown, unpredictable forms. *“Using materials in this way expands the possibilities of reasoning with people´s prior experiences”* and *“prompts them to pick up the materials and get started”* (p.59).

- *Materials and phenomena are evocative and invite inquiry*.

Materials used to experience have to be “beautiful, complex, surprising and observable on their own”. Not only are favourable materials provided but also materials that *“are slightly flawed or that do not fit together perfectly, so that they require more thinking, effort, and ingenuity to get them to work as planned”* (p.59).

- *Tools and concepts of science are a means, not an end*.

Activities are created to allow learners to create and experience by themselves so that they develop the understanding of scientific concepts, phenomena and tools. While investigating and constructing things, students get familiar and confident with the concepts, phenomena and tools and *“develop intuitive understanding, facility, and comfort with science and scientific concepts and* *tools, creating the conditions in which they are more likely to continue to engage"* (p.60).

- *Multiple pathways are readily available*.

The design of the activities should enable multiple ways to reach the final outcome. This allows the learners to test their hypothesis, prosper on their understanding and physically represent their ideas and understanding. Multiple pathways available also make it possible for the teacher to clearly see if the learners know about scientific concepts, phenomenas and tools. First of all, learners explore and, second of all, they observe, test and experience failure and success. Accordingly, there is not an established way to carry out the activity.

- *Activities an investigations encourage learners to complexify their thinking over time*.

Apart from providing multiple pathways and alternatives to carry out the activity, we need to challenge the learners by offering *"opportunities for complexification as the learner progresses toward understanding a principle, concept, or function"* (p.61). Here materials that can be used in different ways and for different functions are essential.

Nonetheless, learning is not just an individual construction of knowledge. Collaboration is gaining weight in our society so projects should be carried out in environments which invite collaboration and sharing of ideas, aspect that I develop in the following subsubsection.

2.2.2. Social environments

Until now learners have been participating in communities that enabled each individual to construct their personal knowledge through experience. However, education of the 21st century should be based on creativity, innovation and what Ackermann calls "sharism".

In this respect, many educators seek to create social environments that enable learners to collaboratively learn as well as to provide support to each other in order to succeed (Gutwill et al., 2015). Collaboration consists of action but also of dialogue and communication. Thus, special importance is not given to be competitive but to be capable of sharing knowledge, ideas, opinions and experiencing with each other in order to overcome any possible setback. It means that not only can learners take advantage of each other's strengths but they can also compensate for weaknesses (Dale et al., 2010).

Collaboration and sharing of ideas is extremely important in our society due to globalization as it requires people to internationally collaborate and cooperate. For this reason, educators should form people able to work in group dynamics and share experiences and knowledge to fulfil a task or face a challenge rather than students whose knowledge is excellent but are not prepared to share it as they have not developed their social competence dimension in problem-solving situations.

Four principles for *environmental design* that we should take into account and in which the importance of the social dimension can be clearly spotted (Petrich et al., 2013):

- *Past project examples and current activities are situated to seed ideas and inspiration*.

It is advisable to display other productions so that the learners can get inspired, compare and refer to others constructions when creating their own. This may help them to overcome and confront difficulties.

- *Activity station design enables cross-talk and invites collaboration*.

The space is distributed in a way that encourage cooperation. Learners tend to negotiate and support each other as they are sharing the same space. It is a good idea to limit the amount of materials at their disposal so that they need to share them and interact. This environmental design *"leads to natural discussions and conversations between learners, and acknowledgment of what each person is working on, and an opportunity for help and feedback at every point along the way"* (p.62).

- *Studio layout supports individual initiative and autonomy*.

Although collaboration is vital on these kind of practices, personal autonomy can not be avoided. Learners need to have initiative and move around in order to find materials and tools that can be used to develop the activity. They have to struggle to find a solution, new ideas and inspiration.

- *Activity adjacencies encourage the cross-pollination of ideas*.

Materials and tools are placed on one table so that everyone needs to move to this area to find the materials and tools needed to develop their ideas. This is great when it comes to share solutions and overcome difficulties that can be encountered by more than one group. If we foment proximity we are also promoting the shifting of information and sharing of ideas so that when someone is stuck or success, the others can take part of it.

2.2.3. Facilitation

Facilitation is crucial for a science practice based on a constructivist point of view that involves learning by doing and inclusive social environment as unavoidable aspects to reach deeper learning of scientific concepts. Learners are considered to be on the centre of the learning process as they direct, develop and experience their own ideas. This directly implies that teachers are facilitators. Facilitators have to support the learner's ideas and encourage them to continue developing them.

Here are *three principles for facilitation* during the development of the student's ideas (Petrich et al., 2013):

- *The facilitation is welcoming and intended to spark interest.*

The facilitator has to welcome the learner to the project and tell them that everyone has their own place and importance on it. It is also important to make them know that the facilitator will be there to support them during the whole process. Besides, it is a good idea to place materials in front of the learners and show them some examples or models to engage them on the project and help them to start thinking of ideas.

- *Facilitators try to focus learners' attention, based on individual paths of understanding.*

The facilitator should observe and talk to the learners in order to spot the ideas or concepts they want to apply and, consequently, to be able to suggest them tools and materials to explore those ideas. Nonetheless, support and help do not have to be provided too early as it can result in students giving up without making an effort to overcome the difficulties and get unstuck. The key is to drive the learners attention to materials or tools that can be helpful to move forward and advance once they are stuck.

- *Facilitators should strengthen understanding by helping learners clarify their intentions through reflective conversation.*

Getting stuck and unstuck is the best learning opportunity. Facilitators should challenge students asking questions in order to go deeper on their idea. They should make pupils think about their productions. If their productions work, learners may feel successful, but it does not mean that they have perfectly understood scientific concepts and ideas. For this reason, it is advisable to challenge learners to apply their idea to another context, materials or design.

2.2.4. Deeper learning

Professionals in education are currently worried about how can children deeply and correctly understand complex scientific concepts by experiencing and coming up with their own conclusions.

> “If knowledge cannot be imparted, and if knowledge must be a matter of personal construction, then how can children come to knowledge of complex conceptual schemes that have taken the best minds hundreds of years to build up?” (Matthews, 1998, p.8).

Undoubtedly, children cannot build up such theories and practices without their equals and teacher´s support, but we cannot ignore *“children´s natural tendency to invent for themselves the supports and mediations they need to reach their goals, whenever the tasks they face lay beyond their mastery”* (Ackermann, 2004, p.25).

Teachers can teach scientific concepts and theories to students in a way that they memorize and reproduce the information as they have received it, but is it actually meaningful learning? Are they actually acquiring the content and developing their competences in order to be capable of acting in the real world? We need people capable of using knowledge rather that reproducing it. If we want this to happen, educators must encourage students to explore, manipulate and deal with unforeseen circumstances in order to successfully overcome them. Thus, students develop the capacity of adapting themselves to whatever the situation is and to be able to cope with the unexpected, which is especially important in current society.

Society demands and education need to go on the same direction. We need people who think critically, find several solutions in order to solve complex problems, adapt to the unexpected, work collaboratively, communicate effectively and learn by themselves. Individuals must be competent when successfully managing their own life in both professional and personal aspects. In this respect, rather than meaningful learning I would like to point out the concept of "*deeper learning"* (Deeper Learning, 2012) which is the aim of this work. There are four strategies to promote deeper learning: personalised learning, project-based learning, work-based learning and competency-based learning. Basically, these strategies consist of individual learning, experiencing and representing your own ideas, applying your ideas collaboratively and showing and sharing your discoveries (The Alliance, 2011).

Scaffolding is what makes knowledge available to students. It must be provided to make students feel comfortable and save to confront new challenges. To be able to provide this support, it is necessary to refer to Vygotsky´s concept of *the zone of proximal development* which is the potential zone of an individual in which learning can occur and which is directly related to the present ability of the students. Educators must be aware of the present ability of the learners in order to be able to think of different ways to provide learners with the appropriate support to push them just beyond their present ability and enable them progress on their learning (Ackermann, 2004; Dale, Van der Es, Tanner & Timmers, 2010). Accordingly, materials and contents should be increasingly complex, or spiral curriculum (Bruner, 1960) should be taken into account. Scaffolding regarding present ability of the students and spiral curriculum are required to promote deeper learning.

Learners interact with different tools and materials and try to physically represent an idea. As it has been previously said, during the process they need to face various obstacles. When trying to overcome these problems, they get stuck and then, unstuck. These situations in which learners experience success and frustration while struggling to find a solution to the problem allow them to develop authorship, purpose and deep understanding of the concrete scientific issue that has been developed. Undoubtedly, this is the most meaningful part of the process in which students can meaningfully learn (Petrich et al., 2013; Gutwill et al., 2015).

Therefore, the experience should be designed to promote deeper learning as well as to *"spark and support people's active engagement and learning – in particular, fostering the process of inspiration, creativity, frustration and breakthrough"* (Petrich et al., 2013, p.58).

2.3. Previous experiences

Recent practices carried out in the Tinkering Studio support this constructivist approach for learning science. The Tinkering Studio (http://tinkering.exploratorium.edu/) is a space for collaboratively exploring, investigating and creating as well as to enhance creativity and new ideas. It is located in San Francisco Exploratorium and it has developed several activities and programs related to art, technology and science for museum visitors. The initiative to carry out this kind of projects in various museums begun in 2000, and it resulted in an innovative way of learning science and technology by using small devises called "crickets". Currently, the project has been gradually spread to other museums and learning environments.

The Tinkering Studio makes materials, tools and technology available for museum visitors to investigate and represent their ideas during several activities. They create and design the activities and programs regarding the five principles for designing an activity, the four principles for environmental design and the three principles for facilitation in which this work is based. Taking these principles into account, they design opportunities for learners to develop their competences and physically represent their ideas.

Learning in the exploratorium is recognized by paying special attention to the engagement, intentionality and solidarity of the visitors. Experiences show that it is not about an opportunity to play and having fun with science, but it is about being engaged in contextualised and purposeful practices that enable learners to develop valuable knowledge and skills. Moreover, learners are learning how to learn at the same time they are creating and generating new personal ideas.

Thus, we can state that learners are engaged and deeper learning takes place *“in the evidence-based practices of science and engineering, with the artifacts themselves providing evidence for learning as well as evidence of learning, in a creative and joyful learning environment”* (Petrich et al., 2013, p.69).

This present work reflects principles from the Exploratorium and others regarding deeper learning to reach scientific knowledge. To do so, I have to take deeper learning, social environment, learning by doing and facilitation into account. I want students to share, to explore, to tinker[1] (Petrich et al., 2013) as I strongly believe it makes a remarkable difference in learning science. I must say that this approach is not new as there are previous experiences in the Exploratorium that show effectiveness. These experiences are related to electricity, circuits and programming. However, I would like to apply the approach to human science and, concretely, to the structure and locomotion of animals, a field that has not been included before.

3. SCIENCE-IN-ACTION PROPOSAL

My proposal consists of three lessons related to the structure and locomotion of animals; the first focuses on warms, arthropods and vertebrates corporal development plans in terms of adaptation to the environment, resistance and agility; the second is based on the structures that are needed to support and move the human body structure and on which characteristics do they have to meet to accomplish their function; and the third is about different types of bones, their characteristics and their suitability when it comes to provide the human body skeleton with support, resistance and mobility. According to discovery learning and spiral curriculum (Bruner, 1960) the design of the three lessons is not casual but differs in levels of concretion. Lessons go from the overall to the particular and are designed to be carried out either as a whole or separated. When separating them, I propose lesson 1 is for children aged 7-8, lesson 2 is for children aged 9-10 and lesson 3 is for children aged 11-12. However, every lesson could be adapted to each level as are the four methodological aspects which make it possible to reach scientific knowledge

1 Tinker is a new way of learning which consists in exploring, creating and experiencing failure and success in collaborative activities.

regardless of complexity. Lessons must be adapted to the group's specific needs.

In any case, what lays behind the entire proposal is the methodological framework. The sequence of activities is not casual (Sanmartí, 1997). Without exception lessons begin with exploration and manipulation of explicit materials provided. The manipulation and exploration of materials takes place in a concrete learning by doing and inclusive social environment where facilitation is regarded. This is what is going to provide learners with proper opportunities to test and reflect on their own ideas as well as to experience failure and success in order to reach conclusions and deeply learn science from their own experience. Besides, it must be said that it is necessary to set some tasks for pupils to know what they are expected to explore, test and create. This allows them to successfully produce the final outcome in which they apply their ideas and scientific knowledge.

The final outcome includes a personal creation and a poster regardless of the lesson. The physical creation is the representation of the learner's own ideas which should allow them to deeply understand and acquire scientific knowledge. The poster reflects the whole learning process of students and consists of four quadrants: knowledge formulations after each session, creation process, collaboration and cooperation between the members of the group and between groups, and contextualization of the creation with the structure and locomotion of animals. Instead of traditional A3 cardboard posters and as far as technological resources are available, I recommend using an interactive tool online called *"Glogster"* (*www.glogster.com)* which allows the user to create interactive posters or *"glogs"*.

The main aim of this work is to test the effectiveness of its methodological approach aimed to reach deeper learning in favour of learning by doing which happens in a social environment in which facilitation is provided. For this reason, I include an oversight of lessons 1 and 3, and I deeply develop lesson 2. The first ones are composed of their conceptual and methodological framework according to Gowin's "V" and their session's distribution. This is for educators to have the possibility of implementing them in future practices. Notwithstanding, lesson 2 includes, apart from its Gowin's V and session's distribution, its lesson plan and assessment in detail. I strongly believe that lesson 2 perfectly illustrates the method I want to reflect on the entire proposal. Moreover, it is implemented in The Mount, a preparatory school in England (section 4) in order to observe and analyse the methodological aspects that I have considered most appropriate to learn science.

The following subsections correspond to each lesson in order.

3.1. Lesson 1: Three corporal development plans

3.1.1. Introduction

Lesson 1 is designed to give response to *which corporal development plan is the ideal depending on the environment* and to *which is the most optimal in terms of resistance and agility.*

First of all, I propose the first session to be delivered to understand physical fundaments which are necessary to successfully develop the exploration and experimentation. This exploration is related to test resistance, resistance-lightness, and mobility of the structures created by the learners. After this, they have to realise which structure simultaneously maximizes resistance and movement and, consequently, decide how to improve it, take the challenge and optimize it. Once they have tested structures regarding the characteristics of the three corporal development plans (warms, arthropods and vertebrates), they create a final structure simultaneously maximizing resistance and movement. The structure is defended at the end of the lesson. Moreover, they present their poster which consists of the four sections established: knowledge formulations, creation process, collaboration and cooperation between the members of the group and between groups and contextualization. To conclude, it is important to contextualize and identify each of the pupil's structures with one of the three corporal development plans. Finding similarities and reaching conclusions enable learners to answer the driving questions of the lesson.

The following subsubsection shows the conceptual and methodological frame for lesson 1.

3.1.2. Conceptual and methodological frame: Gowin´s V

Following is the conceptual and methodological frame for lesson 1 (**figure 1**).

Knowledge in V

CONCEPTUAL

THEORIES

- Theory of evolution and how evolution leads to adaptation.

-Structure-Function

PRINCIPLES

- Biological evolution principle of heredity: mutations, at random.

- Biological evolution principle of natural selection: the most successful or fittest when surviving in/adapting to a specific environment.

- Structure-function

CONCEPTS

- Hydrostatic pressure
- Atmospheric pressure
- Push
- Flotation
- Magnitudes → Force
- Resistance
- Resistance – lightness
- Mobility

DRIVING QUESTIONS

- Which corporal development plan is the ideal depending on the environment?

- Which corporal development plan is the most optimal in terms of resistance and agility?

EVENTS/OBJETS OF STUDY

(1) Physical fundaments

- Get to understand the following physical fundaments: hydrostatic pressure (water-air circuits), atmospheric pressure, push, float and force (pull/push).

- Test resistance, resistance-lightness and mobility of different materials and structures created by the learners → Optimization.

Find out which structure has the maximum of resistance and mobility regarding both parameters at the same time → optimization.

(2) Creation of a structure regarding maximum resistance-mobility → Optimization.

(3) Oral defence of the structure created

(4) Contextualization: identify each structure with one of the three corporal developments.

METHODOLOGICAL

VALUE CLAIMS

- To be sensible to and aware of diversity.

- Deep learning. Motivation,engagement, sharing, manipulation and experimentation to meaningfully learn science.

– Sharism to confront any problem-solving situation.

KNOWLEDGE FORMULATIONS

- Hydrostatic pressure makes it possible for warms to move. They have high mobility but little resistance.

- Arthropods have high resistance to any force but they have just a little mobility.

- Vertebrates have the most suitable corporal structure when it comes to simultaneously maximize resistance and movement.

- There are different corporal development plans. All corporal development plans are valid. Each one works for an specific environment.

DATA AND TRANSFORMATIONS

(1) Tables for data collection (they will have to build it or it will be provided by the facilitator depending on the level of students)

(1) (2) Selection of data which maximizes resistance-lightness.

(3) teacher´s final assessment grid & peer-assessment grid.

(4) To match the structures created with corporal developments.

REGISTER

(1,2,3,4) Stuck-unstuck register.

(1) Resistance, resistance-lightness and mobility of materials and structures constructed with them (data collection).

(2) Resistance and mobility of the structures created (data collection). Photographs of the creation process.

(3) Photographs of the final structures and posters. Defences recordings.

(4) Photographs of the contextualization (structure – corporal development plan).

Figure 1. Gowin's V for Lesson 1

3.1.3. Session´s distribution

Lesson 1 is divided into four sessions (**table 1)**. Each session leads to the following one in order to reach the final outcome.

Table 1. Lesson 1: session´s distribution.

		Session	*Timing*
1	Physical fundaments	1.1. Previous physical fundaments	120 minutes
		1.2. Testing physical properties	
2	Creation	2.1. Structures' creation	120 minutes
		2.2. Physical conceptualization & Optimization	120 minutes
3	Defence		60 minutes
4	Contextualization		60 minutes

3.2. Lesson 2: Vertebrates. Bones, muscles and elastic elements.

3.2.1. Introduction

Lesson 2 is designed to give response to *which structures are needed to move and support our skeleton* and to *which characteristics do they have to meet to be able to accomplish their function.*

The lesson starts with the exploration of the uses of three different materials. Each material has clear properties and function related to our bones, muscles and tendons/ligaments. After conceptualising the materials with the human body frame, it is time for creating a structure taking all previous concepts into account. In the end, the children defend their structure to be the best at the function they propose. They relate their structure to the human body frame as well as they present their poster which consists of the four sections established: knowledge formulations, creation process, collaboration and cooperation between the members of the group and between groups and contextualization.

The following subsubsection shows the conceptual and methodological frame for lesson 2.

3.2.2. Conceptual and methodological frame: Gowin´s V

Following is the conceptual and methodological frame for lesson 2 (**figure 2**).

Knowledge in V

CONCEPTUAL

THEORIES

- Theory of evolution. How evolution leads to adaptation.

-Structure-function: elements of the musculo-skeletal system.

PRINCIPLES

- Biological evolution principle of heredity: mutations, at random.

- Biological evolution principle of natural selection: the most successful/fittest when surviving in and/or adapting to a specific environment.

- Skeleton's support and flexibility

CONCEPTS

Musculo-skeletal system:

- Bones (support)

- Muscles (elasticity)

- Ligaments and tendons (join).

DRIVING QUESTIONS

- Which structures are needed to move and support our skeleton?

-Which characteristics do they have to meet to be able to accomplish their function?

EVENTS/OBJETS OF STUDY

(1) To deduce and investigate three physical properties:

- Supporting: carton/sticks.
- Elasticity: elastic bands.
- Join: woollen thread.

To negotiate the properties of the three materials as well as what they can be used for.
(2) To conceptualise properties and uses of each material with the human frame. The teacher builds up a structure (made out of carton/sticks, elastic bands and woollen thread).
(3) To create a structure. They have to represent bones, muscles and ligaments/tendons with the materials previously tested for support, flexibility and join.
(4) To defend/present one's creation.

METHODOLOGICAL

VALUE CLAIMS

-Deep learning. Motivation, engagement, sharing, manipulation and experimentation to meaningfully learn science.

-Sharism to confront any problem-solving situation.

KNOWLEDGE FORMULATIONS

-Bones structure (skeleton) provides support to the human body.

-Muscles are attached to bones and enable them to move and stand in a specific position. This is possible due to their flexibility.

-Tendons join muscles to bones so that when there is a muscular contraction the bone that is attached to the muscle moves. Ligaments strengthen joints. Moreover, they optimize the whole movement and enable muscles to function better.

- Vertebrates structure is complex. It needs bones, muscles and elastic elements to move. Bones provide support, muscles provide flexibility and effect the movement, and ligaments join muscles to bones so that the move together.

DATA AND TRANSFORMATIONS

(1) (2) Tables for data collection (they will be either built by the learners or provided by the teacher)

(4) Assessment grid / Self-assessment grid → knowledge formulations and sharism.

(1)(2)(3)(4) Indicators and descriptors of methodological approach development.

REGISTER

(1) - Photographs will be taken when pupils are making use of carton/sticks, elastic bands and pita fibre. Each photograph will show the use they have done of each of them (qualitative data). - Register of all the uses and functions that pupils attribute to each material.

(3) Photographs of the creation process.

(4) Poster: collaboration, knowledge formulations, creation process and contextualization; presentations are recorded; peer-assessment.

(1) (2) (3) (4) Self-assessment after each session (knowledge formulations and collaboration).

Figure 2. Gowin's V for Lesson 2

3.2.3. Session´s distribution

Lesson 2 is divided into four sessions (**table 2**). Each session leads to the following one in order to reach the final outcome.

Table 2. Lesson 2: session´s distribution.

	Session	*Sub-sessions*	*Timing*
1 & 2	Exploration & Conceptualization		120 minutes
3	Creation	3.1. Structure creation	120 minutes
		3.2. Optimization & Defence design	120 minutes
4	Defence		120 minutes

3.2.4. Lesson plan

As it is been said in the previous subsubsection, lesson 2 is going to be divided into four different sessions: exploration, conceptualization, creation and defence. Each part leads to the next one so that, at the end of the block, pupils create their own final outcome which shows their understanding and knowledge acquisition. The final outcome for Lesson 2 consists of a structure and a poster. The structure is made out of carton, elastic bands and woollen thread and it has to be created taking our human body structure into account. At the end of the lesson, learners defend their structure to be the best at the function they propose and contextualise it with the human body frame. They also present their poster created since the beginning of the lesson till the end of it so that it reflects their learning process.

Below is the lesson plan which includes the development of each session in depth (**table 3**).

Table 3. Lesson plan for Lesson 2

Lesson 2. Vertebrates. Bones, muscles and elastic elements.

Sessions	*Lesson general objectives*
1. Exploration 2. Conceptualization 3. Creation 4. Defence	• To be able to identify which structures are needed to move and support the skeleton. • To be able to identify which characteristics bones, muscles and elastic elements do have to meet to be able to accomplish their function.

Session 1. Exploration	
Learning Objective (LO)	To be able to identify the physical properties and function of three different materials from manipulation and exploration of their uses.
Teacher´s role • To facilitate. To provide materials. To take photographs.	*Learner´s role* • To explore and manipulate the materials provided.

Description

In this session inquiry and investigation are invited. Pupils are encouraged to explore and manipulate. They are asked to manipulate materials and "play" with them in order to discover their uses and, consequently, their physical properties and functions.

Specifically, they are provided with three different materials which are already known by them: carton/sticks, as an example of support; elastic bands, as an example of elasticity; and woollen thread, as an example of join. Nevertheless, they are not told anything about the properties and functions of these materials as I want them to investigate and find out their own personal pathway for reaching conclusions. Therefore, there are multiple pathways allowed and every solution, idea and observation is welcomed. Moreover, during the exploration learners get familiar and confident with the materials, they are motivated and engaged.

Regarding social environment, students can move around and share ideas. This does not mean copying other's observations but getting inspired and collaborating.

Once students have had enough time to investigate and test the materials provided, it is time to negotiate physical properties (rigid/indeformable, flexible and elastic), functions (support, elasticity and join) and uses (open answer) that can be attributed to each material. It should be carried out out-loud and supported by the teacher through reflective conversation so that everyone can benefit from each other's discoveries. Learners present the uses that they have associated to each material and make a demonstration in front of the rest of the class. The qualitative data is collected in the *material's exploration grid* (annex I.a.i). The data is analysed by the learners in order to find out which is the main function and properties which lay behind their findings.

At the end of the session, each group writes a paragraph that best shows what they have observed and learnt in this session (knowledge formulations). They do it on their poster, specifically, on quadrant 1 for knowledge formulations.

Finally, they self-assess their work regarding knowledge formulations and collaboration/cooperation/sharism.

Tasks

- Task 1: find out which uses can be attributed to the following materials: carton/sticks, elastic bands and woollen thread. Write your findings down in the material's exploration grid. It is an open task. Every answer is welcomed.
- Task 2: share your findings with the rest of groups. Come to an agreement about what each material is best for.

(For this task they are not told anything about support, elasticity and join)

- Task 3: match each material with one of the following functions: support, elasticity and/or join.
- Task 4: which physical properties lay behind the functions attributed to each material?

* Physical properties: what you can observe or measure.

- Task 5: What have you learnt in today's session? Discuss it with your group and write at least three statements (one statement per material) on your poster on quadrant 1. (annex I.b.i).

- How was my work today?: Place your name on the face that best shows how you are doing when it comes to both knowledge and collaboration with your group and between your group and other groups (annex II.b.i).

Resources

- Materials: Carton/ sticks, elastic bands, woollen thread.
- Poster (A1/A3 cardboard) or *"glog"* (www.glogster.com).
- Digital camera.
- Material's exploration grid (annex I.a.i).
- Poster's arrangement (annex I.b.i).
- Self-assessment: How was my work today? (annex II.b.i).
- Teacher's register grid: How was my work today? (annex II.b.ii).

Register

- Photographs are taken while pupils are making use of carton/sticks, elastic bands and pita fibre. Each photograph must show the use attributed to each material by the pupils (qualitative data).
- Uses, properties and functions attribute to the materials.
- Knowledge formulations for session 1 (quadrant 1 of the poster/glog).
- Teacher's register grid: How was my work today?

Data and transformations

- Pupils analyse the data collected in the table and come to an agreement about the function and properties of each material.
- General assessment (annex III).

Assessment: Continual assessment.

- Self-assessment: How was my work today?

Session 2. Conceptualization

Learning Objectives (LO)	To be able to match the physical properties and function of each material with the human frame (bones, muscles and tendons/ligaments).

Teacher´s role	*Learner´s role*
• To facilitate (reflective conversation).	• To actively participate in the reflective conversation.

Description

Session 2 has to do with the conceptualization. In other words, this lesson is for learners to give meaning to their previous exploration. Before, they have experienced and discovered the uses of three materials and, consequently, their functions and physical properties. It is important for pupils to analyse and be aware of the associations that can be made between the physical properties and functions of these three materials and the physical properties and functions of our bones, muscles and tendons/ligaments. Thus, it is the teacher who shows and contextualises these functions and physical properties in the human body structure through reflective conversation.

Taking the *material's exploration grid* into consideration, the teacher builds a simple structure made out of carton, elastic bands and woollen thread to seed inspiration of ideas. Cross-talk and collaboration takes place between the whole group of students. They get inspired from each other's ideas as well as from the teacher's structure creation. This will enable them to develop the next session in which they have to create their own structure.

At the end of the lesson, each group writes a paragraph that best shows what they have observed and learnt in this session. They do it on their poster/glog, specifically, on quadrant 1 for knowledge formulations.

Finally, they self-assess their work regarding knowledge formulations and collaboration/cooperation/sharism.

Tasks

- Task 1: Can you find any similarities between the properties of carton/sticks, elastic bands and woollen thread and our bones, muscles and tendons/ligaments?

Scaffolding for task 1: Which are the characteristics of *bones*? Which is their function? Can you find any function of the materials that we have being looking at that could be related to bones? Which are the physical properties of bones? Can you find any physical properties of the materials that we have being looking at that could be related to bones?

*Ask the same scaffolding questions regarding muscles and tendons/ligaments. Define one element and once they have reflected on it, move on to the next one. After providing students with scaffolding questions on bones, muscles and tendons/ligaments, go back to answer task 1.

Visual support: The teacher shows students the human body development plan through *zygotebody* (www.zygotebody.com), a 3D anatomy viewer and interactive tool which allows you to have a look at different layers and parts of the human body, spot elements such as bones, muscles and ligaments/tendons and observe the way they are placed to accomplish their function.

- Task 2: The teacher creates a structure taking all the students ideas into consideration and negotiating with them how to place the three materials in order to have a structure able to stand (support) and move. The educator makes questions about physical properties and functions regarding human body structure (reflective conversation).
- Task 3: What have you learnt in this session? Discuss it with your group and write a paragraph on quadrant 1 on your poster/glog. (annex I.b.i).
- How was my work today?: Place your name on the face that best shows how you are doing when it comes to both knowledge and collaboration with your group and between your group and other groups (annex II.b.i).

Resources

- Materials: Carton/ sticks, elastic bands, woollen thread.
- Poster (A1/A3 cardboard) or glog (www.glogster.com).
- Computer + projector.
- Visual Support: 3D anatomy viewer, zygotebody (www.zygotebody.com).

- Material's exploration grid (annex I.a.i).
- Self-assessment: How was my work today? (annex I.b.i).
- Teacher's register grid: how was my work today? (annex II.b.ii).

Register

- Uses, functions and physical properties attributed to each material.
- Self-assessment: how was my work today?

Data and transformations

- General assessment (annex III).

Assessment: Continual assessment.

Session 3. Creation

Session 3.1 Structure creation

Learning Objectives (LO)	To be able to create a structure made out of materials which represent bones, muscles and elastic elements regarding support and flexibility.

Teacher´s role	*Learner´s role*
• To facilitate – To provide support when learners get stuck and cannot unstuck after having made an effort. – To challenge learners → Optimize structure.	• To design and create their puppet/structure. • To deal with the difficulties, to confront challenges and to find solutions.

Description

After the contextualization, pupils create their own structure. The creation is open to any design or idea meaning that it does not need to be a body structure, as far as it physically represents knowledge formulations and concepts in different contexts, materials, creations.

As it is being said in Gowin´s V, students should give an answer to which structures are needed to move and support our skeleton as well as to which characteristics they have to meet to be able to accomplish their function. This means that the structure has to stand and be flexible. It is not required to move without any human support, but to be able to effect movement. In other words, it needs to be provided with something which represent our bones, muscles and elastic elements. It is absolutely acceptable to make use of carton/sticks, elastic bands and woollen thread but pupils are also allowed to use other materials which they may find valid and useful for their structures. In whatever way, they have to justify their choices and defend their structure to be optimum regarding support and flexibility.

What is more, the educator encourage students not only to create a structure able to support and move but to create a structure which is the best at certain function or use that they propose. They are not given more guidance but that they have to establish an objective for their structure which needs to be a group decision. For instance, they could decide that their structure is going to be like a ballet dancer so that it needs to be very agile and, consequently, they must have to prioritise elements which provide flexibility.

Regarding activity design, multiple pathways enable the teacher to check the understanding of scientific concepts, phenomena, tools, and knowledge formulations included in Gowin´s V. Furthermore, students will experience failure and success when trying to cope with difficulties and they will have to face challenges and confront difficulties during the creative process. While pupils get stuck and unstuck, the teacher contributes to the complexity of their thinking by suggesting them changes to optimize their structures. Whenever pupils can not get unstuck even if they are making a great effort, the teacher recommends making some changes on the way materials are placed or using different materials so that they can find a solution to the problem, get unstuck and meet with success.

At the end of the lesson, each group writes a paragraph which best shows what they have observed and learnt in the session (knowledge formulations). They do it on quadrant 1 of their poster/glog.

Finally, they self-assess their work regarding knowledge formulations and collaboration/cooperation/sharism.

Tasks

- Task 1: Create any structure providing it is able to support and have flexibility. Propose a function for your structure. It has to be the best at the function you propose.

* It is an open task in which they have to explore. The teacher provides support whenever it is necessary, for example if students get stuck and, after several trials, cannot unstuck by themselves.

* You can use carton/sticks, elastic bands and woollen thread to build your puppet. However, you can also use any material that you think can improve your structure flexibility/support as well as its particular function in which you have decided it to be the best at.

- *Task 2:* What have you have learnt in this lesson? Discuss it with your group and write a paragraph on quadrant 1 on your poster/glog for today's session (annex I.b.i).
- How was my work today?: Place your name on the face that best shows how you are doing when it comes to both knowledge and collaboration with your group and between your group and other groups (annex II.b.i).

Resources

- Materials: Carton/ sticks, elastic bands, woollen thread and any extra materials chosen by the learners to create and/or optimize their structure.
- Poster (A3/A1 cardboard) or glog (www.glogster.com).
- Digital camera for taking photographs.
- Self-assessment: How was my work today? (annex II.b.i).
- Teacher's register grid: How was my work today? (annex II.b.ii).

Register

- Photographs of the creation process.

- Self-assessment: How was my work today?

Data and transformations

- General assessment (annex III).

Assessment

- Continual assessment.

Session 3.2 Optimization & Defence Design

Learning Objectives (LO)	• To be able to test support and flexibility on one's creation. • To design visual materials for supporting an oral defence/presentation. • To reflect on group work and to be able to say how it contributes to physically represent ideas and acquire knowledge formulation.

Teacher´s role	*Learner´s role*
• To facilitate To challenge students to optimize their structures. To clarify the items that pupils have to include in the oral defence.	• To reflect on their creation. • To suggest improvements. • To contextualise their own creation. • To reflect on their learning process and group work.

Description

Once students have designed and have created their structures, it is time to test them regarding support and flexibility. This will help them to reflect on possible changes and improvements. The teacher challenges them asking questions about what their structure is able to do and if it could do it better (reflective conversation).

Afterwards, each group designs its oral defence. The oral defence consists of two parts: a *performance* and a *poster*. The performance has to demonstrate what the structure is able to do and which aspect it is the best at. The *poster´s explanation* has to cover the four quadrants: knowledge formulations, creation process, collaboration and cooperation between the members of the group and between groups and, finally, contextualization in relation with the human body.

Finally, they self-assess their work regarding knowledge formulations and collaboration/cooperation/sharism.

Tasks

- *Task 1:* test your structure mobility and support. Is there any way you could improve it? Watch out for the materials you have used and how you have placed them.
- *Task 2*: test your structure when it comes to be the best one at something. Is there any way you could improve it? Watch out for the materials you have used and how you have placed them.
- Task 3: decide on the performance that best shows what your structure is able to do and what it is the best at. Give reasons. You can take a look at quadrant 1 on your poster/glog (knowledge formulations).
- Task 4: Create your final poster to support your defence. The final version has to consist of four parts (annex I.b.i; annex I.b.ii).
- How was my work today?: Place your name on the face that best shows how are you doing when it comes to both knowledge and collaboration with your group and between your group and other groups (annex II.b.i).

Resources

- Poster/glog.
- Structure created.
- Materials: carton/stick, elastic bands and woollen thread.
- Digital camera for taking photographs.
- Poster's arrangement (annex I.b.i).
- Driving questions for section 3 of the poster (annex I.b.ii).
- Self-assessment: How was my work today? (annex II.b.i).
- Teacher's register grid: How was my work today? (annex II.b.ii).

Register • Photographs of the creation process. • Self-assessment: How was my work today?	
Data and transformations • General assessment (annex III).	
Assessment • Continuous assessment.	
Session 4. Defence	
Learning Objectives (LO)	• To explain and defend one's creation giving reasons for the materials used and saying which characteristics these materials meet to support the structure and to provide it with flexibility. • To explain the relationship between their structure and the human body structure.
Teacher's role • To record presentations. • To assess.	*Learner's role* • To present and defend one's creation. • To peer-assess. • To self-assess.
Description Students defend their structure to be the best at something by testing it in front of the rest of students and giving reasons. Moreover, they explain their poster going through its four quadrants. Special importance is given to creation process, group work and contextualization. While each group presentation is taking place, the rest of groups fill in the *peer-assessment grid* (annex II.a.i). After the presentations, they discuss and share the strengths and possible improvements that they have observed on their classmates creations so that everybody can learn form each other and	

obtain instant feed-back on the work. It is carried out out-loud.

Tasks

- Task 1: What is your structure best at? Test it in front of the rest of the class and give reasons for its success.
- Task 2: Explain your poster. You must talk about the four parts included on it (use your poster to support your presentation).
- *Task 3:* Peer-assessment. Assess your classmates' defence. Be sensible and polite. The assessment is for us to learn from each other and improve our work. Make suggestions which could help your classmates to improve. (annex II.a.i).
- How was my work today?: Place your name on the face that best show how are you doing when it comes to both knowledge and collaboration with your group and between your group and other groups (annex II.b.i).

Resources

- Structures created.
- Posters to support the presentation.
- Digital camera (photographs/video).
- Peer-assessment grid for structure defence (annex II.a.i).
- Teacher's assessment grid for structure defence (annex II.a.ii).
- Knowledge formulations assessment grid (annex III.a.iv).

Register

- Final poster/glog.
- Presentation recordings.
- Peer-assessment grid for structure defence.
- Teacher's assessment grid for structure defence.

Data and transformations

- Pupils analyse their notes about each other's defences and point out the strengths of each structure as well as they make suggestions for improvement (peer-assessment grid).

- While presentations are taking place, the teacher fill in the final assessment grid (knowledge formulations and sharism). It is checked having a look at all the posters and defence recordings.
- General assessment (annex III).

Assessment: Final assessment

- Structure defence (peer assessment)
- Structure defence (teacher's assessment)
- Knowledge formulations assessment

3.2.5. Assessment

The assessment focuses on knowledge formulations as well as on sharism, collaboration and cooperation. Students are continuously assessed throughout the sessions by the teacher, their classmates and themselves regarding both aspects. Specific rubrics have been created for it (annex II; annex III). Some of them are filled in after analysing the data registered (grids, photographs, recordings...) and others are filled in from class' observations.

Apart from knowledge formulations and sharism reached by students, it is important to analyse if this methodology based on constructivism, exploration and sharism is successful when it comes to designing and carrying out science proposals in the science class. For this reason, specific indicators and descriptors had been created to assess the teaching-learning progress (annex III). This rubric allows educators to conclude if this approach helps students to internalize and deeply learn scientific knowledge formulations as well as it helps teachers to know wether sharism, collaboration and cooperation makes a difference when it comes to develop scientific knowledge, competences and skills or not.

Therefore, rubrics are the tool that is used for assessing the teaching-learning process, the proposal design and the principles and methodology which drive this work.

3.3. Lesson 3: The skeleton. Types of bones.

3.3.1. Introduction

Lesson 3 is designed to give response to *which different types of bones form human's skeleton that provide it with support, resistance and mobility* and to *which type of bones is the most suitable for each function.*

The lesson is structured similarly to lesson 2. First of all, learners explore and manipulate materials which are a clear example of long tubular bones and flat compact bones, and they test them in regard to support/resistance and mobility in relation to mechanic advantage and twisting. Once they have tested the materials, they are conceptualised with the skeleton. After this, it is time for them to create. Creation can be done either optimizing the structure from lesson 2, in case lessons have been implemented as a whole, or creating a new structure from scratch. In the end, they defend their structure and relate it to the human's skeleton as well as they present their poster which consists of the four sections established: knowledge formulations, creation process, collaboration and cooperation between the members of the group and between groups and contextualization.

The following subsubsection shows the conceptual and methodological frame for lesson 3.

3.3.2. Conceptual and methodological frame: Gowin´s V

Following is the conceptual and methodological frame for lesson 3 (**figure 3**).

Knowledge in V

CONCEPTUAL

THEORIES

- Theory of evolution
- Structure-function: bones

PRINCIPLES

- Biological evolution principle of heredity: mutations, at random.
- Biological evolution principle of natural selection: the most successful or fittest when surviving in/adapting to a specific environment.
- Functions of the skeleton: support/protection and assisting movement.

CONCEPTS

- Support
- Mobility
- Long/short/flat bones
- Compact/spongy bones

DRIVING QUESTION

- Which different types of bones form the human skeleton that provide the skeleton with support, resistance and mobility?

-Which type of bones is the most suitable for each function?

EVENTS/OBJETS OF STUDY

(1) Guided exploration and manipulation of different materials which are examples of long tubular bones and flat compact bones. Learners will test support/resistance and mobility. Mobility will be observed and tested regarding two different aspects: mechanic advantage (lever arm) and twisting.

(2) Conceptualise the materials previously tested with the skeleton.

(3) Optimize the structure created in lesson 2 taking the conclusions reached in (1) and (2) into account.

(4) Learners present to the rest of the class their structure improvements and justify their choices regarding resistance, support and mobility. Besides, they conceptualise it with the skeleton (long tubular bones and flat compact bones).

METHODOLOGICAL

VALUE CLAIMS

- Deep learning. Pupils are motivated, engaged and understand the theoretical concepts through experimentation.

– Sharism to confront any problem-solving situation.

KNOWLEDGE FORMULATIONS

- Long tubular bones provide more mobility than flat compact bones. For this reason, long tubular bones form the limbs.
- Flat compact bones are more resistant than long tubular bones. For this reason, flat compact bones provide protection to the human body organs.
- The human body skeleton consists of different types of bones. Both of them are necessary as long tubular bones provide mobility and flat compact bones provide support and protection.

DATA AND TRANSFORMATIONS

(1) Learners analyse the material and shape which is best for each function: resistance/support and mobility.

(3) Before-after structure comparison.

(4) - Assessment grid → The teacher analyse knowledge formulations and competences developed by the learners.

- Self-assessment grid → learners reflect on their learning: knowledge formulations and competences acquired as well as make suggestions on possible improvements.

REGISTER

(1) (2) Photographs of the process will be taken. Learners will collect data about the resistance/support and mobility of the materials and structures tested.

(3) Photographs of the optimization will be taken.

(4) The teacher collect data in a rubric regarding the following items: register of the changes that learners have done to their structure; resistance/ support of the structure after optimization; mobility of the structure after optimization; learners justification of the changes in relation to different types of bones and its function; difficulties confronted during the process; learners suggestions for improvements.

Figure 3. Gowin's V for Lesson 3

3.3.3. Session´s distribution

Lesson 3 is divided into four sessions (**table 4**). Each session leads to the following one in order to reach the final outcome.

Table 4. Lesson 3: session´s distribution.

Lessons		*Sessions*	*Timing*
1	Exploration	1 session	120 minutes
2	Conceptualization		
3	Creation	1 session	60 minutes
4	Defence	1 session	60 minutes

4. IMPLEMENTATION OF LESSON 2 IN THE UNITED KINGDOM

The implementation has taken place in Year 3 at The Mount, St. Mary´s College Preparatory School in Liverpool, the United Kingdom. In this section I contextualise my proposal in relation to *the curriculum in England*, *The Mount* and *year 3 at The Mount* including previous knowledge of students as well as their abilities and class arrangement. I also include the *session's distribution* regarding the school timetable. Finally, there is a subsection for *results.*

4.1. The Curriculum in England

The national curriculum in England (2013) includes programmes of study for key stages 1 and 2 for all the national curriculum subjects including science. The general purpose of science subject is to provide the foundations for understanding the world through biology, chemistry and physics. Different blocks of content are stablished along the Years. Specifically, Year 3 is divided into five blocks. One of them is *Animals, including humans* in which one of the statutory requirements is to be able to *"identify that humans and some other animals have skeletons and muscles for support, protection and movement"* (p.158).

Every school bases its curriculum on the national curriculum in England. Schools are allowed to introduce content earlier or later than it is established in the national curriculum. The Mount does not have a curriculum in such a way.

They have designed their own Levelled Key Skills document for each area of knowledge as well as they follow the *100 Science Lessons for the 2014 Curriculum: Planning Guide* by Scholastic.

4.2. The Mount, St. Mary's College Preparatory School

The Mount is an independent Catholic Primary School for pupils from Reception to Year 6, that is from 4 to 11 years old. As a result, the children who attend the school tend to be from fairly affluent families due to the fee-paying nature of the school. Its aim is to provide students with a safe, caring, creative and motivating environment in which they can develop their abilities to the maximum. They continuously challenge students in order to become skilful, confident and balanced individuals as well as to develop critical thinking.

Unless they develop every single ability of their pupils, they specifically focus on mathematic methods and literacy. Science subject is based on projects methodology. Besides, every month pupils from each Year work on a particular “Theme”, which includes most areas of knowledge and in which science is remarkably involved. In general, children are above national average.

4.3. Year 3 at The Mount

3.3.1. The pupils

Year 3 has already studied some content in relation to the human body. The Mount's lesson plan specifies that Year 3 should be able to describe how joints in our skeleton enable movements, to understand that muscles work in antagonistic pairs and to understand that muscles attached to our bones contract to create movement.

Apart from previous knowledge, it is important to be aware of social and cognitive characteristics of the students. Concretely, Year 3 consists of seventeen pupils of the age of eight. On the one hand, regarding social abilities they can verbalise their ideas and feelings with confidence, have no issues with presenting themselves and tend to do this eloquently. They are also able to work alongside others, with some children taking a more leading role whereas a few children feel more comfortable taking a slightly more passive role. On the other hand, cognitively the children in the class are on the whole above average for their age. In reading most of the class are above national expectations for the end of year and no children are below end of year expectations. In Maths around half of the class are above national expectations for the end of year, with the rest of the class attaining average expectations for their age. With writing around one third of the class are above national expectations for the end of the year and one child is below national expectations. Generally speaking, the children are able to express their ideas scientifically using scientific vocabulary and some of them in the higher ability group in the class are able to provide reasons for their thoughts and ideas. They are beginning to make links and apply their learning within a range of situations and contexts.

Lesson 2 was accomplished in collaborative groups. As they were seventeen, they were divided into four groups: three groups of four members named *Science Kids*, *The Clever Clogs* and *Brain Waves*; and one group of five members named *Super Secret Scientists*. These groups were balanced regarding pupil's social and cognitive abilities. Thus, social and cognitive abilities were taken into account and, consequently, pupils could benefit from each other's strengths and compensate for weaknesses when collaborating and discussing ideas and/or opinions.

4.3.2. Class management

Class management is essential for the proposal to be successful as social environment is one of the main aspects whose principles have been previously established. This means that class arrangement should promote cross-talk and collaboration as well as cross-pollination of ideas. For this reason, desks were organised in five different groups. Every group of pupils worked on one group of desks. The groups were placed around the fifth group of desks in which the materials provided to explore, manipulate and construct were placed.

4.4. Session´s distribution

Sessions have been distributed in relation to the school timetable (**table 5**).

Table 5. School timetable: session´s distribution

Day Time (h)	Tuesday 5^{th} May	Wednesday 6^{th} May	Thursday 7^{th} May	Friday 8^{th} May	Monday 11^{th} May	Thursday 14^{th} May	Monday 18^{th} May
9:00 - 9:30				Session 3.1			
9:30-10:30			Session 3.1 *Structure creation*	*Structure creation* Session 3.2 *Optimization*		Session 3.2 *Defence design*	
Break time							
10:50-12:00		Session 2 *Conceptualization*					Session 4. *Defence*
Lunch time							
13.15-13.45		Session 2 *Conceptualization*			Session 3.2 *Optimization*		
13:45-15:15	Session 1 *Exploration*				Session 3.2 *Defence design*		

4.5. Evaluation

As the methodological approach framework is the essence of this work, I report the results and analyse them in relation to the four aspects I want to reflect on it: deeper learning, learning by doing, social environment and facilitation.

Particularly, my observations on these aspects are based on concrete indicators and descriptors that I have established for each of their principles to be favourable when deeply reaching scientific knowledge (**table 6).**

Table 6. Indicators and descriptors of methodological principles development

Aspects	*Principles*	*Indicators*	*Descriptors (Observation)*
1. Deeper learning	a. Understanding of concepts and application of their own ideas.	Expressing awareness	- Verbalizing understanding
		Representing and experiencing and applying knowledge and one's ideas	- Physically representing an idea.
		Collaborating, showing and sharing discoveries	- Verbalizing/pointing out/showing their own applications of concepts.
2. Learning by doing	b. Enhance motivation and engagement	Spending time in the activities	- Manipulating, exploring, creating, improving, testing.
		Expressing emotions/feelings	- Verbalizing or making gestures that show frustration, pride, satisfaction, excitement, joy.
	c. Is promoted by materials and tools provided	Materials are observable, complex, beautiful and surprising	- Realizing or making gestures that show understanding when they observe/manipulate - Keeping them working and

			optimizing their creations -Making them think and using them as planned
		Tools enable learners to create and experience on their own	- Understanding concepts / getting unstuck / facing challenges while experiencing and constructing.
	d. Allows multiple pathways	Enabling them to explore, observe, test and experience failure and success	- Exploring, observing, testing their own ideas - Experiencing success and failure when applying their own ideas
	e. Encourage pupils to complexify their thinking	Giving alternatives to carry out an activity and taking up challenges.	- Using materials in different ways and for different functions.
3. Social environ ment	a. Enables Inspiration	Getting inspiration from past/other projects	- Applying or testing other's ideas in one's work to overcome difficulties
	Enables cross-talk and collaboration	Requesting or offering help when dealing with difficulties	- Requesting or offering ideas and opinions and/or tools and materials.
		Inspiring new ideas	- Noticing, pointing out, or talking about other's work.
		Physically manipulating together	- Physically creating work together
	b. Enables individual initiative and	Setting one's goals	- Setting a specific purpose - Planning steps for creating - Continuing working outside

	autonomy		the class.
		Responding to feedback	- Actively seeking out materials and tools to fulfil the task
		Not giving up when facing a challenge	- Persisting to get unstuck when they get stuck - Persisting to optimize their creations, discoveries.
		Showing courage and taking risks	- Willing to optimize -Making changes on their structure. Trying new ideas. Taking challenges.
	c. Enables cross-pollination of ideas	Physically sharing spaces (common spaces for all the groups)	- Moving around and sharing common spaces.
4. Facilitation	a. Is welcoming and sparks interest	Feeling important for the work	- Actively participating and taking part of the work
		Offering inspiration	- Starting thinking of new ideas from materials and resources offered.
	b. Focus on individual paths of understanding	Suggesting tools or materials to explore their own ideas	-Observing and talking to the learners to spot their ideas -Driving their attention to helpful materials and tools (not too early)
	c. Strengthen understanding (reflective conversation	Reflecting on their discoveries/creations and enabling them to continue	- Asking questions to go deeper on the learner's idea - Asking questions to reflect on their creations

)	discovering/creating	- Challenging them to apply the ideas to another context, material or design.

Source. Prepared by the author on the bases of Gutwill, J.P.; Hido,N.; Sindorf, L. (2015). An Evidence-based Framework for Observing Learning during Tinkering Activities. *The Museum Journal,* 1-28.

In addition, observations and comments on these principles are progressively gathered during the implementation. I use the *Results Observation Grid for Methodological Principles and Proposal Adaptation to School* (annex III.a).

4.6. Results

In this subsection I describe the results and analyse the strengths and limitations of the implementation of *Lesson 2* at *The Mount*. It is important to point out that the results are observable on the register which consists of tables, pictures and recordings. Every register allowed in terms of data protection has been included in this present work (annex IV.). Concretely, *material's exploration grid*, *teacher's register: how was my work today* and *final outcome (glogs)* are attached.

1. Deeper Learning

Deeper learning is the first aspect to bear in mind and it is this work's final aim. The final outcome, which is the defence and the glog, reflects the understanding of concepts and application of the student's ideas which is the last step when it comes to the sequence of activities in constructivist approaches (Sanmartí, 1997). My first indicator *expressing awareness* is evident when they wrote their statements at the end of each session. The statements reflect a general understanding of physical properties and functions unless there is some inaccuracies as Super Secret Scientists appeared not to be aware of functions and woollen thread properties. They also made good matches between materials and the human body structure using their own words as *“our muscles are like elastic because they are bendy, they give us flexibility”, “bones are like carton that help us standing up” or “tendons are like woollen thread because they join our muscles and bones together” ,* and I could find some difficulties with woollen thread as The Clever Clogs stated *"Our joints are like string because they join together with the joints, they give us flexibility and movement"*. As a matter of fact, they clearly had great difficulty when creating. For instance, Brain Waves wrote *"we used carton for buildings and the pool. We used elastic band for the pool and castle. We used woollen thread for flags and signs".* Nevertheless, I found positive progress over time as, next session, they stated *"we used a lot of carton for the castle and our buildings. It gives support to them. We used elastic band for flags and stretchiness. We used woollen thread to join out castle"*. Exceptionally, Super Secret Scientists' progress is not obvious on the poster but if we move on to the next indicator *representing and experiencing things applying knowledge and one's ideas,* they made a marvellous use of woollen thread and carton. At the end of the creation, Science kids' slingshot most outstanding feature was flexibility, The Clever Clogs' factory and Brain Wave's park were excellent at standing (support), and Super Secret Scientists' puppet was proficient at joining. Every group demonstrated being proficient in at least one function and aware of the other two, with the exception of Super Secret Scientists and Brain Waves which were not able to represent flexibility.

Furthermore, I would like to report the first indicator in relation to the contextualization of the structure with the human body frame. They *verbalised understanding* of the function of the materials used in their structures as well as of the function of bones, muscles and tendons/ligaments in our body. In fact, they either connected this two aspect using *"this is similar to"* or did not connect them.

Lastly, the third indicator *collaborating, showing and sharing discoveries* took place when working as a group to overcome setbacks. Every group verbalized and showed their discoveries and creations either between the members of the group or to me.

Analysing deeper learning, students were MA (Medium Average) at the end of the lesson. Exploration and application of their own ideas enabled them to meaningfully learn and to be capable of applying and sharing ideas collaboratively. This approach has certainly contributed to develop their competences and reach deeper learning of scientific concepts. Although they did not precisely match their structures to the human frame, they physically represented them which implies that they did apply knowledge. Defending is a higher cognitive process that may require more time (Anderson & Krathwohl, 2001). Year 3 students were not able to provide reasons for their thoughts or ideas yet, or they were starting to do so. I strongly believe that more time for creating and optimizing their structure would have made a significant difference on their contextualizations. In the last session, they showed a strong improvement so that it suggests that they were on the right path. Obviously, the implementation was demanding but I am certainly convinced that learners deeply learnt those scientific concepts that they could explore and experience with respect to the time provided.

2. Learning by doing

I have established four aspects to pay attention to with regard to the principles for designing an activity that I had mentioned for *learning by doing* in the theoretical framework. These aspects are: motivation and engagement, materials and tools provided, multiple pathways available and encouraging pupils to complexify their thinking.

a. Motivation and engagement

Motivation and engagement was evident regarding both indicators: *spending time in activities* and *expressing emotions and feelings*. I observed that pupils were extremely motivated in the exploration of materials. They really appreciated having the opportunity to manipulate different materials with complete freedom as well as being allowed to use their imagination and creativity. Several learners doubtfully asked if they could manipulate the materials to create different shapes so that they could use them for different purposes. They expressed joy when I allowed them *"Yeah!"* and excitement *"Miss! Look at my bridge, it's got three columns and string on top!".* Seven children brought their own materials to create their structure verbalizing *"I've brought lots of elastics!"* and showed motivation saying *"I've got this carton and couldn't get more, I'll try to bring more for tomorrow, can I?"* or asking *"Are we starting our structure today?*". During the creation process, they were willing to show their discoveries and explain the ideas they wanted to physically represent. It is remarkable that one pupil requested *"Miss, are we doing science* *today? I need to still working on my doors."* and that a second pupil created a slingshot made out of carton, elastics and woollen thread at home and showed pride *"I made this at home, it's a slingshot, do you want to try?"*. Furthermore, I had feedback from a mother who wrote on a girl's diary *"Ella has had great time at school this week, specially with the science project"*. Furthermore, when we had just the final defence left, they wanted to continue improving their structures and continuously asked for it claiming that their structure was not ready yet.

Therefore, I can conclude that motivation was widespread during the whole process. This principle determines the favourable development of a proposal, and it this case, it was undoubtedly a strong point.

b. Materials and tools provided

Materials provided have as first indicator that they should *be observable, complex, beautiful and surprising*. At the beginning, some pupils found it difficult to imagine materials out of their real uses and contexts and stated *"I don't know how to use it".* However, they started exploring and attributing uses to the three of them. They expressed particular enthusiasm on elastic bands as they asked for them and wanted to use them, or even overuse them. They drew, cut in different shapes and combined colours. When exploring and manipulating, they easily noticed physical properties verbalizing that *"elastic bands are stretchy" or that "you can pull them"* even though some uses they made of them were not related to their real properties and functions. For instance, they used elastic bands as *"water"*, as *"skin"*, as a *"cape"*, *"to cover"* the carton or as a *"smily face"*. Carton's properties and function were really clear as they used carton as *"buildings"*, *"bridge structure"*, "*human body structure"*, "*parts of the body"* or *"rocks"* and verbalized that *"carton can be used to give support"*. Even though I can not say either that they were surprised by carton or that they found it beautiful, I saw them continuously manipulating the carton cutting, drawing and colouring. When it comes to woollen thread, they clearly discovered its function as they used it as "*handcuffs"*, *"to make a braid"*, *"to join pieces of carton"* or to tie their desks. Anecdotally, there were some who represented a *"river"* or *"cheeks"* without taking its function into account. Regarding the creation process, they principally struggled to place elastic bands and woollen thread as they did not take advantage of their properties and function as well as the vast majority forgot about the woollen thread. For example, they placed elastic bands to cover parts of a puppet and woollen thread as if it was the water of a waterfall.

I found that there was a substantial difference in terms of engagement and motivation between carton, elastic bands and woollen thread. It might be that the elastic bands and woollen thread were more colourful than the carton and, consequently, more appealing. Apart from this, some stereotypes were expressed on the manipulation of materials as most of the carton roll made columns and blue elastic bands represented sky or water.

Finally, the indicator *tools enable learners to create and experience on their own* is visible when learners were experiencing and constructing. It was evident how pupils improved on their creations over time. Firstly, they used materials without taking their properties and functions into account but, thanks to investigating and constructing, they gradually became aware of how to use them in order to reach their goals. Science Kids created a slingshot using elastic and carton so that the elastic was directly joined to the carton. When they tested the slingshot, the joint between the elastic and the carton broke and one of them exclaimed *"It is not tight enough!"* and showed understanding reinforcing the joint with woollen thread. Therefore, the group faced the challenge and got unstuck on their own.

Regarding the analysis of this principle, variety of materials and tools as well as shapes and colours are decisive in exploration. It would be advisable to provide learners with a wider range of shapes and colours of each material. This will encourage them to find more uses as they will be more surprising, beautiful and motivating as well as to successfully place them according to their properties and functions. Moreover, it will help them to overcome stereotypes through their own experience. This does not mean that stereotypes are a problem at all. Quite the opposite, starting manipulation and creation from stereotypes it is a strong point as they show individual's own ideas. Nevertheless, more shapes and colours will also benefit learners when it comes to find their own pathways to continue exploring and creating from these first representation of stereotypes.

c. Multiple pathways allowed

At the begging of the lesson, some students stopped themselves from making the most of the exploration of materials because they did not dare to manipulate them without restriction. They continuously asked for permission whenever they wanted to cut, blend, punch or join. It was obvious that they were afraid of incorrectly manipulating them as they wondered *“what if I cut it too small?”* and asked me *“Can I do it?”.* However, it only took place during the first ten minutes of exploration. Along the following sessions, they freely explored and tested their ideas and hypothesis.

Learning by doing *allows multiple pathways* was tangible when pupils explored, observed and tested their own ideas as well as experienced failure and success. On the one hand, The Clever Clogs wanted to create a chocolate factory and sought support prioritizing carton for its structure. Despite the fact that they were using carton regarding its function, the structure could not firmly stand as they had several pieces of carton separated. They tried to join the pieces with elastic but it broke. After several times of trial and error, one pupil found a solution saying *“we can use woollen thread! It was to join things together!”.* On the other hand, Science Kids wanted to create a slingshot. Elastic band was directly joint to the carton and when they tested the slingshot it broke so one of them verbalized that they needed woollen thread *“to tight it”.* The same case can be applied to Super Secret Scientists's puppet when they answered that *“woollen thread joins the puppet to the controller”.* All groups observed and tested their own ideas to conclude that woollen thread's function is joining and they definitely met with success after having experienced failure.

In the end, structures were really diverse: The Clever Clogs made a chocolate factory, Brain Waves created a city park, Science Kids constructed a sling shot and Super Secret Scientists designed a puppet. I asked each of the groups if they could explain how they had placed the materials in comparison to how our bones, muscles and tendons/ligaments are placed in our body. Each of them proved understanding of scientific concepts and knowledge formulations acquired from completely different explorations, observations, tests, failures and success.

I would like to reflect on the fact that some students did not dare to freely explore when they were allowed to do so. Could it be due to the academic environment in which the proposal took place? Students are used to be sat down on their desks and follow certain instructions given to complete a task. They associate classroom and desks with mathematics or literacy and it restricts their imagination and creativity when exploring so that they do not make the most of the experience to find their own pathways. I suggest this methodological approach is undertaken in a room free of desks which is not linked to strict behaviour at schools. Notwithstanding the foregoing and depending on the results, this approach enables multiple pathways to reach the same content, which means that students give meaning to their ideas and the educator can find and attend individual needs. It certainly boosts learning and gives meaning to scientific content.

d. Encouraging pupils to complexify their thinking

Encourage pupils to complexify their thinking is promoted by *giving them alternatives to carry out an activity and taking up challenges*. All the evidence suggests that materials could sometimes be used in various ways and for different functions.

Each and every one started to directly attach elastic bands to the carton or even to join items with elastic bands instead of joining them with woollen thread. When attempting to challenge them to improve the joint, the vast majority said *"I can join elastics to the carton with a node"* so that elastic bands' function could be join. Their personal experience proved that the elastic node was not tough enough to keep the elements tied so that they began to use woollen thread instead. Brain Waves, The Clever Clogs and Super Secret Scientists employed woollen thread to join elements and wrote that it could be used *"to join the towers to the climbing frame", "for joining other materials together and make a wire of chocolate" or "to join the hair and the controller to the body"*. On the other hand, Science Kids took thread to strengthen the joint between the carton and the elastic bands on their slingshot and noted that it *"ties elastic band to the carton"*.

Another obvious example was carton. Sticks gave them the possibility of providing structures with supports, and carton panels were used as bases. They met with success as their structure certainly improved its balance and could stand after adding some carton/sticks. What is more, The Clever Clogs took advantage of combining sticks and carton roll. They wanted to make gears for their chocolate factory so that it could spin. The sticks supported the gears made out of carton roll so that carton was used in different manners and for the same function.

Therefore, materials that can be used in different ways and for different purposes are believed to be essential for the appropriate development of this principle. As a matter of fact, I have been able to finds few cases for its indicators. I do not consider it is my proposal strength as I did provide three materials with clear functions and properties. Nevertheless, I support that having three materials particularly benefits this lesson due to its relation to the human body structure. If we want students to come to an accurate conclusion, we need materials with clear same functions and properties as bones, muscles and tendons/ligaments. Definitely, this proposal contributes to the complexity of the learners' thinking but it could be promoted by providing a wider range of materials as far as they are carefully chosen not to lead to a misunderstanding of the scientific concepts.

3. Social environment

It is been stipulated that activities should be developed in a social environment which enable inspiration, cross-talk and collaboration, individual initiative and autonomy and cross-pollination of ideas. I observe each principle for this aspect regarding its indicators and descriptors.

a. Enables inspiration

In the theoretical framework I have stated that past projects must be displayed around the physical space to seed ideas and inspiration. This is not visible due to a complete lack of previous projects.

In consequence, the indicator for *enables inspiration* is based on *applying or testing other's ideas in one's work*. I could realise that during the exploration the pupils shared their discoveries with each other and got inspired by other's as they tested if the materials were suitable for the use other classmates had attributed to them. Similarly, in the conceptualization they shared their findings and took notes about other's discoveries and tested them afterwards. During the creation process, I hardly found instances of inspiration between groups. As an exception, Brain Waves got inspired by The Clever Clogs when using elastic bands to make a flexible flag. In fact, all got inspiration from members of their group. Collaboration between members of the same group is deeply developed in next principles for social environment.

In my opinion, inspiration requires from a longitudinal study of this methodological point of view so that learner could get inspiration from past projects. As I had not this possibility on my proposal, I can say that inspiration arose from collaboration, cross-talk and cross-pollination of ideas, unless the last one was not frequent enough. My perception was that competitiveness was extremely present among the children and they were afraid of trying other's ideas as they considered it “copying”. It is high time we promoted inspiration and *“sharism”* at schools. I can not assure it a golden road but I certainly think that results will gradually be remarkably favourable if we work on encouraging current generations to share in order to develop competences and reach knowledge.

b. Enables cross-talk and collaboration

The first indicator I have developed for this principle, is *requesting or offering help when dealing with difficulties*. I fostered collaboration by restricting the amount of materials at their disposal. This made them either experiencing the materials together or having the need of asking for them which led to natural discussions. As an example, a boy from The Clever Clogs was working on where to place elastic bands so that they could tauten when some gears rotated. He was about resigning to failure when another member of the group asked him for some elastics and they started commenting on how to tackle the problem. He realized his ambition after deliberating and deciding with his mate that elastic bands could be attached with woollen thread from gear to gear. Another example is when a child stated *“carton could be used to support the structure of a bridge”* and offered himself to explain the meaning of support to those who had not heard this word before saying *“support means to maintain something, for example, our bones support our body so we can stand up”*. Thanks to his contribution, they could conclude that carton's function is support and that it is directly related to our bones.

The second indicator is *inspiring new ideas* which was confirmed as a pupil pointed out the woollen thread that another student was using to join elastic band to the carton and tried the same on his creation. It enabled him to achieve success. Besides, Brain Waves talked about The Clever Clogs's structure and decided to incorporate a flag made out of the three materials on their creation.

The third indicator occurs when learner's *physically manipulate together* materials and tools to co-create the structure, as when a boy created a chocolate tube that would connect to a girl's chocolate wires.

It must be said that each and every group positively valued group work on their final presentations and posters. Them all agreed that working in groups had given them the opportunity to come up with ideas, confront challenges and be assured of success.

To conclude, cross-talk and collaboration is being a strictly essential principle of this work. I believe that the children would not have been capable of fulfilling the final outcome without their classmates' support, including knowledge formulations and creation process. Thus, cross-talk and collaboration were strongly present during the implementation of lesson 2 and made it possible to students to take up challenges, to not give up whenever they encountered difficulties and to keep on being engaged and motivated to represent their ideas.

c. Enables individual initiative and autonomy

Not only must social environments promote collaboration and cooperation but they must also foster individual initiative and autonomy.

Regarding *setting one's goals*, some students continued constructing outside the classroom as they were not given more time to create at school. They brought their new creations to school and proudly shared them with everyone. On the contrary, there is little evidence of planning in order to achieve certain goals as they made decisions and took action as problems, new challenges and achievements came.

Responding to feedback is noticeable when they continuously tested their structures and introduced changes for improvement. Notwithstanding, it was really difficult for them to be aware of some of their creation weaknesses. As a consequence, at the end of the creation process I provided them with a checklist (annex II.a.i) that enabled them to self-assess their own creations. Thus, they could receive feedback and realize which aspects they were missing and needed to optimize. Their responses in terms of optimizing structures were excellent as they focused on encountering the particular setbacks that they had spotted.

Anecdotally, some pupils gave up and did not accept the challenge whenever their trials continued resulting in failure. They appeared to be doomed to failure but demonstrated strong personal motivation as they carried on applying their knowledge to physically represent different ideas. With the exception of these few cases, *not giving up when facing a challenge* was widespread among pupils. It was remarkable a boy who was extremely committed to create the doors of a factory using the three materials. Although he did not achieve success (it could be that he had not enough time for creating, testing and reflecting), he persisted seeking new ideas, possible changes and solutions for the doors to have flexibility along the whole process.

Showing courage and taking risks when they became aware of one their creation's shortcomings and tried their best to sort it out by making changes and applying new ideas. A girl from Super Secret Scientists realised that the puppet had not flexibility. They had employed elastic bands but they were just covering the carton. Willing to optimize was obvious as she verbalized *"I need the puppet to move some parts of its body"* and made several slight changes to finally arrive to the conclusion that was elastic band the material that was going to give flexibility to the puppet. What was particularly interesting was the high degree of courage they showed at the end of the project compared to the lower determination they manifested at the very beginning.

The children were, therefore, very committed to the work. I dare to say that the activity enabled individual initiative and autonomy although the age of the students was decisive as personal initiative and autonomy was not enough developed yet. Students did not have enough strategies to plan their exploration and creation in order to reach an objective. However, they clearly sat their goals, actively responded to feedback, were persistent and showed courage. More than likely, the increase in the degree of courage could be because students were not used to work from this methodological point of view. This suggests that once students get used to explore and experiment by themselves, they gain in self-confidence as well as dare to take risks and confront unforeseen difficulties.

d. Enables cross-pollination of ideas

The indicator that I have created for enabling cross-pollination of ideas is *physically sharing spaces.* What I did to facilitate it was placing all the materials in the middle of the classroom so that every group needed to go there if they wanted to take materials to manipulate, prove and construct. I saw it when two boys happened to meet in this area and one suggested *"if you tie the elastic band there it will move"* what resulted in the other boy overcoming the difficulty he was having trying to place the elastic band. In addition to the materials' disposal, there was interaction between two groups as Brain Waves needed more carton and The Clever Clogs had some carton spare. When Brain Waves requested carton, they explained their structures to each other.

Apart from physical space, conceptualizing out-loud promoted cross-pollination of ideas as they shared their findings and the vast majority took notes of each other's discoveries on their own initiative.

When designing the visual support for their structure defence, it was clear that they do not appreciated the chance of getting inspired from other groups as they pointed out *"we didn't need to take any idea from others"* and showed pride making gestures. What is more, some seemed to be afraid of recognizing been inspired by other's ideas and only said it when I emphasised that it was a positive aspect for the project.

In the end, there were just few evidences of cross-pollination. Transference of ideas was stopped because there was not enough space in the classroom for the pupils to move around due to the high amount of desks in comparison with the physical space available. It would be advisable for this approach to take place in wide spaces where the children can comfortably move around. In addition and reassuring my previous words for inspiration, I certainly believe that is competitiveness what restricted cross-pollination of ideas when it comes to share ideas, knowledge and physical representations between groups so that educators should encourage pupils to understand “sharing” as a positive value that enable us to develop ideas and overcome difficulties.

4. Facilitation

Facilitation is a vitally important aspect of this work. Balanced scaffolding-autonomy is crucial for the learner to learn science from a constructivist approach that promotes learning by doing which takes place in a social environment and it is aimed to reach deeper learning of scientific concepts. I comment each principle for facilitation according to my indicators and descriptors.

a. Is welcoming and sparks interest

I can assert that pupils were *feeling important for the work* as every member was actively participating and taking part. They reflected excitement thought gestures, smiles and sounds such as *“Yeah!”* when they were told that every contribution and personal idea was welcomed and could be put into practice. Besides, these pupils are used to know the learning objective at the beginning of each session in every subject at school so I decided to write each session's learning objective on the board. I observed that they felt more confident as they had a clear idea of what was expected from them. Subsequently, they were really interested in reaching the learning objective and worked hard for it. At the end of the lesson some expressed satisfaction *“Yes! I've got it!”* and others disappointment when they thought they did not get it by saying *“I´m not sure if I got it...”* or making doubtful faces.

The other indicator is *offering inspiration.* I either suggested they try different materials or drove their attention to a concrete structure as a model to seed new ideas. I can assert its effectiveness as it certainly helped them to apply new ideas and make best use of resources and, subsequently, to improve on their work.

b. Focuses on individual paths of understanding

Due to the fact that there is not a unique pathway to carry out the activities, facilitation must focus on individual paths of understanding. My indicator is *suggesting tools or materials to explore their own ideas*, and I did so talking to the learners and walking around. It enabled me to identify their own ideas so that not only could I recommend them explore certain materials and tools but I could also encourage them to accept challenges. For instance, The Clever Clogs were using elastic bands for joining and they were absolutely convinced that it was the best material possible to tie the chocolate tube to the flag. I could figure it out when asking them how they were doing. I drove their attention to the woollen thread and challenged them to use it on their chocolate tube. After some attempts, they came to me and enthusiastically exclaimed *“we have tied it better and now is much more fixed!”.* From then on The Clever Clogs used woollen thread to join everything on the structure what suggests they had interiorised its function and properties. Similar cases can be reported in relation to every group.

I must say that I found this principle essential as this is how I knew the needs of the pupils and could think of strategies to assist their progress. Basically, they encountered difficulties such as making an agile structure by placing elastic bands taking its function into account, using woollen thread to join elastic band to the carton, physically representing accurate ideas (sometimes, not having enough ability to create made them think their hypothesis was wrong when it was not) and forgetting about the purpose they had prioritised on their structure.

c. Strengthen understanding through reflective conversation

Reflecting on their discoveries/creations and enabling them to continue discovering/creating is another key aspect of facilitation. I asked questions to go deeper on the their idea about uses attributed to each material. They deduced each material function and properties thanks to reflective conversation in which they actively took part. After questioning *“Which used have you attributed to carton in here?”*, they stated that carton could be employed “*as structure”.* I continued asking *“then, which is the function of the structure of a bridge?”* to what a girl replied that it could be *“the support of a bridge”* and ended explaining that support means *“to maintain something, for example our bones support our body so we can stand up”.* Besides, I also asked questions to reflect on their creations as *“how have you join this part? - with elastics.. - and era you satisfied with the joint? - No, because I can´t tight it more... -Could you strengthen the joint with another material? - mmm..I don´t know.. - Is there any material at your disposal which function is joint? - oh yeah! Woollen thread!”*.

Another example when a Brain Waves' girl was covering carton with elastic bands and I raised the following questions and got feedback *“”which is the function of elastic bands? - elasticity – Which are their properties? - They are stretchy – Are you taking advantage of their function here? - ups, no...” and started reflecting on how to use them accurately.* Again, two groups asked for glue to join the carton *“Is it really necessary? Do you have any material that you could use to join?” and they doubted “maybe...woollen thread?”*. Finally, I challenged them to apply their ideas to other designs *“I can see that here you have join the elastics to the carton so that it is more agile! What about this part over here? Could you make it more flexible?”* and they decided to try to place elastic on the other side of the factory. At any case, this last indicator has few evidence as they had not enough time to create, reflect on their ideas, succeed and apply to other contexts.

Taking into account the evidences for the three principles for facilitation, I maintain that facilitation is crucial for a science practice based on a constructivist approach aimed to reach deeper learning through learning by doing which takes place in a social environment. Facilitation was demanding in terms of time and responses to individual understanding. This proposal should be implemented with no more than 15 pupils per teacher. Not only would it allow the teacher to provide students with the facilitation they need at any time but also to personally know children and respond to individualities such as pupils who are too impulsive and need to be refrained or pupils who need to be supported to take an active role in the group. Due to facilitation, the children felt important for the proposal and, consequently, showed self-confidence, were involved and willed to create and meet the objectives. My perception about offering inspiration is that it was positive in terms of the children' responses which implies that in caring environments children are more willing to expose their feelings and thoughts. Facilitation was also necessary to help learners to think of ideas which contributed to their understanding and application of scientific concepts. Moreover, teachers need to observe and to talk to the learners to spot their ideas. This is the only way to be able to drive their attention to helpful materials and tools as well as to strengthen understanding through reflective conversation. Both, observation and conversation, were vital on the implementation of this proposal and made a substantial difference in the learning process of the students. I must say that initiative and scaffolding were balanced unless it is difficult to conclude because of the evident lack of time for optimizing their structures. In any case, I can conclude that under no circumstances should these indicators (facilitation is welcoming and sparks interest, focuses on individual paths of understanding and strengthen understanding through reflective conversation) be forgotten as they are one of the essential keys for this proposal to be successful.

5. DISCUSIÓN

El objetivo de este trabajo era reflejar y testar, a partir de una propuesta didáctica, el enfoque metodológico constructivista. Para ello, se establecieron tres aspectos a tener en cuenta que son: *learning by doing* o aprender haciendo, *social environment o* ambientes sociales y *facilitation* o facilitación, que se consideraron requisitos previos para asegurar *deeper learning* o aprendizaje profundo; y se definieron los principios esenciales para que los tres aspectos contribuyan a que el aprendizaje científico sea profundo. A partir de este marco, se plantearon tres bloques de contenido para trabajar ciencias, y se desarrolló en su totalidad el segundo bloque, referente a la estructura del cuerpo humano; mas concretamente, a los elementos que permiten su movilidad y sostén, es decir, los huesos, músculos y tendones/ligamentos. Se pretendía que el alumnado comprendiera las funciones y propiedades físicas de los elementos estructurales a través de la representación física de sus propias ideas y utilizando, para ello, tres materiales con funciones y propiedades análogas a las de los huesos, los músculos y los tendones/ligamentos. Este segundo bloque se llevó a la práctica en el colegio de educación primaria *The Mount* en Reino Unido, lo que posibilitó obtener evidencias de los tres aspectos y analizar si contribuyen positivamente al alcance profundo del conocimiento científico así como sus fortalezas y limitaciones en la puesta en práctica.

La metodología de *Learning by doing* favoreció la adquisición de conocimiento y aprendizaje al fomentar la libertad para construir y destruir sus propias representaciones físicas a partir conocimientos e ideas individuales. Se puede afirmar que algunos conceptos se aprenden mejor en contacto directo con el material sobretodo en ciencias y, como muestran otras experiencias, en matemáticas (Muñoz, 2014). Se alcanzó un elevado nivel de motivación y entrega, evidente en el tiempo que dedicaron a desarrollar la tarea y en las expresiones de alegría, orgullo, satisfacción y también de insatisfacción o frustración, entre otras. La manipulación de materiales ayudó al alumnado a sacar su propias conclusiones y a llegar a comprender conceptos abstractos ante los que presentaron dificultad. El tipo de materiales y herramientas utilizados fue decisiva en estas prácticas porque permitieron observar, deducir, comprender y aplicar funciones y propiedades físicas específicas de los huesos, músculos y tendones/ligamentos. Es necesario que los materiales tengan funciones y características muy claras para facilitar que se asocien o asimilen a las propiedades físicas reales de las estructuras. No obstante seria enriquecedor trabajar con mas variedad de colores y formas para ayudar a superar los estereotipos y fomentar la imaginación.

Esta metodología de aprender haciendo permite que cada individuo escoja su propio camino para comprender los conceptos y alcanzar el conocimiento (Petrich et al., 2013), lo que contribuye a identificar las ideas del alumnado y a conocer sus necesidades individuales para facilitar el aprendizaje teniendo en cuenta, por lo tanto, la diversidad. Se comprobó que, a partir de estructuras completamente diferentes que reflejaron las ideas de cada individuo (Ackermann, 2004; Gilbert, 2004) y su evolución, el alumnado llegó a comprender y aplicar mismos conceptos científicos de manera significativa. Dejar libertad para explorar, investigar, construir pero teniendo *un* objetivo o conocimiento científico al que llegar, puede parecer contradictorio. Las críticas al aprendizaje por descubrimiento apuntan que el alumnado no puede descubrir espontáneamente los conocimientos científicos que ha llevado a expertos siglos desarrollar (Matthews, 1998). Marcar objetivos es necesario para conducir al alumnado hacia el alcance del conocimiento científico. El aprendizaje por descubrimiento, el aprender haciendo, se refleja en el camino y la experiencia personal que permite alcanzar el conocimiento profundamente.

El éxito del aprendizaje basado en la experiencia personal está directamente supeditado a *social environment* o al ambiente social en el que se desarrolla la actividad. Los principios que lo caracterizan, que son, *promover la inspiración*, *la transferencia de ideas*, *la colaboración* y *la autonomía e iniciativa personal*, resultaron ser efectivos y observables en la práctica y, aunque hubo limitaciones, hicieron que la exploración, creación y conceptualización fueran enriquecedoras y efectivas. Es notable como la inspiración entre miembros de un mismo grupo de trabajo fue imprescindible para superar las dificultades y alcanzar el objetivo final (Gutwill et al., 2015). Como demuestran los comentarios al trabajo en grupo de los estudiantes, el alumnado no hubiese sido capaz de llegar al mismo nivel de complejidad de no ser por el soporte y colaboración de grupo. No obstante, la iniciativa y autonomía personal es vital y los resultados fueron positivos. En general, quitando casos muy puntuales, el alumnado marcó sus propios objetivos, ya que trabajó en sus construcciones fuera del horario escolar por iniciativa propia, buscó materiales y herramientas para crear, no abandonó ante las dificultades, aceptó nuevos retos y tomó riesgos.

No obstante, los principios propuestos para el ambiente social se pueden optimizar. Se puede mejorar la inspiración en proyectos anteriores si trabajamos con esta metodología de forma consecutiva para poder disponer de proyectos realizados con anterioridad y distribuirlos físicamente en el espacio. A su vez, es recomendable trabajar la colaboración y transferencia de ideas entre los grupos de trabajo como valor positivo para avanzar en el conocimiento, dejando a un lado la competitividad. Por último, tener en cuenta la planificación de pasos para alcanzar el objetivo, cuya ausencia en esta experiencia podría deberse a la etapa de desarrollo evolutivo en la que se encuentran los alumnos, pero que con facilitación por parte del profesor puede llevarse a cabo.

El papel del docente como *facilitador* es estrictamente necesario. El profesor constructivista debe proporcionar los contenidos que se necesitan en el orden adecuado, establecer objetivos y dar ejemplos de rutinas y procedimientos. Hizo factible que el alumnado avanzara en la representación de sus propias ideas, optimizara y superara las dificultades reflexionando en sus producciones para alcanzar el conocimiento científico. Informar de que el profesor va a estar apoyando el proceso y que todos ellos son importantes en su desarrollo, ayudó a mejorar la confianza para explorar y construir a partir de las propias ideas, se sintieron parte importante del trabajo y tomaron un papel activo en el. También fue eficiente promover la inspiración ofertando materiales, recursos y poniendo ejemplos a partir de los cuales el alumnado pudo pensar nuevas ideas, mejoras y soluciones. Se necesitó observar y hablar con los participantes para conocer las necesidades individuales así como lo qué querían aplicar y testar en sus producciones, información que fue necesaria para dirigir su atención hacia materiales y herramientas útiles para reflexionar y avanzar en el conocimiento. En la misma línea, destacar la importancia de las preguntas, fundamentales como instrumento mediador en el aprendizaje (Sanmartí, 1997). Las preguntas fueron la herramienta básica para la facilitación pues es a través de una continua conversación basada en pregunta-respuesta como el alumnado consiguió profundizar en sus ideas, reflexionar sobre sus creaciones y aplicar sus ideas a otros contextos, materiales o diseños.

No obstante, el papel de facilitador no es fácil. No hay una fórmula exacta que permita al docente saber cuándo debe intervenir facilitando las herramientas para que puedan sobreponerse a las adversidades. Resultó complicado equilibrar la facilitación y la exploración autónoma. Se resolvió a través de la observación y el diálogo, que permitieron intuir el conocimiento de los alumnos reflejado en su experiencia personal para poder decidir el momento propicio en el que el docente debe intervenir y ayudar al alumno a continuar sin llegar a frustrarse y perder la motivación de manera irreversible.

En lo referente al objetivo a cumplir, *deeper learning*, puedo concluir que el alumnado alcanzó conocimiento científico a partir de la representación física de sus propias ideas en un ambiente de colaboración y transferencia de ideas. No solo permitió el aprendizaje individual sino que también construyeron conocimiento en grupo aplicando, experimentando y compartiendo entre iguales (Deeper Learning, 2012). La posibilidad de enfrentarse a las dificultades mediante la búsqueda autónoma de soluciones, supuso reflexión individual y colectiva de ideas propias, las cuales fueron modificándose paulatinamente para superar obstáculos (Petrich et al., 2013). La experiencia ha mostrado que, la manipulación, experimentación y representación física de ideas personales son clave. No obstante, debo señalar que desarrollar el *deeper learning* requiere más tiempo que el planificado dentro del bloque 2. Mas tiempo para permitir que el alumnado reflexione sobre sus representaciones, las optimice, modifique sus conocimientos previos e ideas y contextualice las estructuras que ha creado con la estructura y locomoción de los animales.

En esta experiencia se ha constatado que los cuatro aspectos y sus respectivos principios para diseñarlos están interrelacionados, no podemos separarlos ni obviar ninguno de ellos si queremos lograr que la experiencia de aprendizaje sea lo más efectiva y significativa posible. Queda evidente que todos y cada uno de los principios promueven y favorecen el aprendizaje científico profundo de tal forma que capacita al individuo para aplicar las ideas significativamente.

Desde los comienzos de este trabajo se cuestionaba el por qué de la escasa aplicación de los enfoques constructivistas cuando son considerados, desde años atrás, una alternativa didáctica a la educación tradicional (Matthews, 1998; Tobin, 1993). El presente trabajo ha evidenciado que este enfoque es mucho más exigente, no es camino fácil desde el punto de vista didáctico, y como tal, presenta algunos requerimientos para poner en práctica. Estos factores o necesidades a tener en cuenta son: la proporción profesor/alumno, el tiempo, la distribución de sesiones en el tiempo, la programación de aula, el espacio, la edad del alumnado y la competitividad como valor.

El desarrollo de la propuesta se vio favorecido por las características del centro educativo que permitió trabajar con 17 alumnos. La proporción profesor/alumno debe ser la adecuada para poder dar respuesta a todas las necesidades individuales y facilitar el aprendizaje de manera personalizada, siendo recomendable, de acuerdo con esta experiencia, una relación de 15 alumnos por docente o inferior. Por este mismo motivo, el *tiempo* dedicado a desarrollar la propuesta debe ser mayor para posibilitar que el alumnado reflexione y modifique las ideas superando las dificultades y aceptando nuevos retos. Actualmente encontramos currículos sobrecargados. En ellos se introducen nuevos contenidos como las TICs, las competencias como extra, la promoción de la salud...sin quitar o recortar los ya existentes. Se mantiene el mismo tiempo para trabajarlos, lo que significa que no se puede dedicar a cada uno de ellos el tiempo que necesitan (Coll, 2006). Este enfoque metodológico, necesita dedicarle más tiempo a cada bloque trabajado, ya que no importa el contenido en sí sino la forma de llegar a el, adquirirlo y ser capaz de aplicarlo representando las ideas personales en una construcción física. Posiblemente sea mucho más enriquecedor, desde el punto de vista del aprendizaje profundo basado en competencias. Se trata de comprender y saber aplicar las funciones y propiedades físicas de los huesos, músculos y tendones/ligamentos en vez de limitarnos a aprender los nombres de todos los huesos y músculos del cuerpo humano. La *distribución de sesiones*, debe permitir el desarrollo continuo de una cada sesión para que el alumnado pueda encontrar sentido al proceso de aprendizaje y las programaciones de aula deben ser flexibles, adaptándose a las necesidades del alumnado. En cuanto al *espacio*, este debe ser amplio y posibilitar la movilidad para permitir desarrollar al máximo el potencial de los ambientes sociales. El aprendizaje por proyectos es recomendado por la LOMCE (Ley Orgánica para la Mejora de la Calidad Educativa) como metodología a favorecer, en la que la división de asignaturas en el tiempo, las calificaciones numéricas y los espacios rígidos hasta ahora presentes en el sistema educativo no tienen ningún sentido. La *edad del alumnado* no supone un problema pero debemos tenerla presente para adaptar las propuestas a sus necesidades. El bloque 2 trata contenido y conceptos abstractos que se pudieron trabajar gracias a la contribución y diseño de los cuatro aspectos, pero debe asignársele más tiempo para establecer relaciones entre las representaciones físicas con el cuerpo humano. Así mismo, los más pequeños necesitan facilitación para planificar los pasos a seguir para alcanzar el objetivo que ellos mismos se proponen. En cuanto a la *competitividad como valor*, se debe favorecer la colaboración, o "*sharism*", frente a la competición, transmitiendo que si se comparten ideas, aprendizajes y descubrimientos en comunidad, todos los miembros de la comunidad ganan y aprenden más (Ackermann, 2013).

Existen experiencias previas en el *Exploratorium* (http://tinkering.exploratorium.edu/) que ponen en práctica estos principios en actividades relacionadas con la tecnología y, a partir de esta propuesta, vemos que puede aplicarse a otras áreas de conocimiento científico, como la biología. No solo se trata de conocer cómo funciona la estructura y locomoción de los animales, y mas concretamente en el bloque 2, nuestros huesos, músculos y tendones/ligamentos, sino de llegar a comprender los fundamentos físicos e ideas elementales que subyacen detrás de todos ellos, concretamente sus correspondientes funciones, propiedades físicas y su relación para efectuar el movimiento y sostener nuestro cuerpo. Este tipo de propuestas todavía no se encuentran consolidadas pero con la práctica e investigación-acción docente pueden ser una de las claves para reformar con éxito la manera de aprender ciencia en educación.

La investigación-acción y la experiencia educativa es la que permite encontrar soluciones y alternativas propicias para mejorar el proceso de aprendizaje. La propuesta diseñada teniendo en cuenta *learning by doing, social environments* y *facilitation* con sus correspondientes principios, permiten alcanzar no solo conocimientos científicos como tal, sino que permiten el aprendizaje profundo, o *deeper learning*, del alumnado. El diseño posibilita el desarrollo de capacidades experimentando, representando las ideas propias, aplicando ideas en grupo y compartiendo avances y descubrimientos (Deeper Learning, 2012). Por este motivo, merece la pena que el sistema educativo, los centros y los profesionales de la educación apuesten por ellas y contribuyan a afrontar y superar las limitaciones que actualmente se encuentran en su práctica.

CONCLUSIONES

Este trabajo ha posibilitado establecer y definir los aspectos metodológicos a tener en cuenta para desarrollar con éxito una propuesta de naturaleza constructivista que permita alcanzar el aprendizaje profundo, o *deeper learning,* de conocimiento científico. Estos aspectos se reflejaron en el diseño de una propuesta didáctica en relación a la estructura del cuerpo humano. Analizando los resultados de su implementación, se pueden concluir los aspectos imprescindibles a tener en cuenta y algunas limitaciones a superar en la práctica educativa.

Los *aspectos imprescindibles* para diseñar una propuesta didáctica que permita el aprendizaje profundo, o *deeper learning*, de conocimiento científico son:

- Fomentar el aprender haciendo, o *learning by doing* (Ackermann, 2004; Ackermann, 2013; Bruner, 1960; Gilbert, 2004; Gutwill et al., 2015; Petrich et al., 2013; Muñoz, 2014):
  - Proporcionando y estableciendo contacto directo con materiales y herramientas que permitan observar, deducir, comprender y aplicar el conocimiento científico.
  - Promoviendo que el alumnado represente físicamente ideas individuales y colectivas a partir del material y las herramientas proporcionadas, y así alcance conocimiento científico a través de su experiencia.
  - Diseñando actividades que puedan resolverse de múltiples formas y permitiendo que cada individuo escoja su propio camino para alcanzar el aprendizaje.
- Desarrollar la propuesta en un ambiente social, *o social environment* (Ackermann, 2013; Petrich et al., 2013; Sanmartí, 1997):
  - Promoviendo la inspiración, colaboración y transferencia de ideas entre los participantes a través del trabajo en grupo, la disposición de materiales y herramientas en un lugar común y los espacios abiertos que permitan movilidad.

- Promoviendo la iniciativa y autonomía personal marcándose objetivos propios, aceptando nuevos retos y tomando riesgos en la aplicación de ideas propias

- Definir el papel del profesor como facilitador del aprendizaje, o *facilitation*, que debe actuar (Petrich et al., 2013):
  - Proporcionando los contenidos, materiales y herramientas que se necesitan en el momento y el orden adecuados.
  - Estableciendo objetivos.
  - Dando ejemplos de rutinas y procedimientos.
  - Observando y dialogando para intuir el conocimiento del alumnado y poder intervenir facilitando materiales, herramientas y contenidos en el momento más adecuado.
  - Sirviéndose de las preguntas como instrumento mediador para la facilitación que permite al alumnado reflexionar a partir de su experiencia y alcanzar sus propias conclusiones (Sanmartí, 1997).

Las *limitaciones* encontradas que hay que superar en su práctica educativa son:

- La *proporción profesor/alumno;* de acuerdo con esta experiencia, es recomendable una relación de 15 alumnos por docente o inferior para facilitar el aprendizaje adecuadamente.
- El *tiempo* disponible y la *distribución de sesiones* en el tiempo; se debe romper con las ataduras de los currículos sobrecargados que impiden dedicar a los contenidos el tiempo que nos gustaría y necesitan (Coll, 2006). Este enfoque metodológico requiere tiempo para explorar y aplicar ideas propias y alcanzar el objetivo final, el aprendizaje profundo de los contenidos.
- La *división del tiempo en asignaturas, las calificaciones numéricas y los espacios rígidos;* impiden que el alumnado perciba la estructura de su propio aprendizaje y evita el completo desarrollo del potencial del

ambiente social. Además, *n*o tienen sentido desde el aprendizaje por proyectos, considerada la metodología a favorecer según la LOMCE.

- La *edad* del alumnado; influye directamente en la facilitación y el tiempo necesarios para llevar a cabo la propuesta.
- *Competitividad* como valor; se debe promover el “sharism” frente a la competitividad, transmitiendo que si aprendemos en comunidad, todos los participantes aprendemos más y alcanzamos metas mayores (Ackermann, 2013).

Este trabajo ha evidenciado que este enfoque metodológico es mucho más exigente conceptual y pedagógicamente (Cochran, 1997). Deja constancia de la contribución de *aprender haciendo* o l*earning by doing*, *ambientes sociales* o *social environments* y el profesor como *facilitador* o *facilitation*, al alcance de conocimiento científico profundo, o *deeper learning*, en el campo de la biología. Este diseño posibilita el desarrollo de capacidades experimentando, representando ideas propias, aplicando ideas en grupo y compartiendo avances y descubrimientos (Deeper Learning, 2012). No obstante, el sistema educativo, los centros y los profesionales de la educación deben afrontar y superar las limitaciones de su desarrollo práctico debidas al contexto.

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ANNEXES

A. Annex I. Tables for session's development

a) Specific tables

i. Material's exploration grid

MATERIALS' EXPLORATION GRID			
Group:			
Materials	Use	Function	Physical Property
Carton			
Elastic band			
Woollen thread			

b) General tables

i. Poster's arrangement

1. KNOWLEDGE FORMULATIONS This quadrant is for the group to include every knowledge formulation after each session.	3. COLLABORATION and COOPERATION BETWEEN THE MEMBERS OF THE GROUP AND BETWEEN GROUPS. This quadrant is for the group to include its reflections on *"sharism"*. It is not a closed-answer quadrant but they are given driving questions to reflect on (annex I.b.ii).
4. CONTEXTUALIZATION This quadrant is for the group to contextualise its work.	2. CREATION PROCESS This quadrant is for the group to describe the creation process. They should reflect on and specify the steps they have had to follow in order to achieve their goal (they can have a look at the tasks to help them to remember).

ii. Driving questions for quadrant 3 of the poster

Collaboration and Cooperation questions (quadrant 3 of the poster)
1. How have you felt when working as a group?
2. Has every member of the group participated?
3. How have you deal with having different opinions? How have you manage to come to an agreement?
4. Has it benefited you to work in groups in order to acquire and apply scientific knowledge?
5. Have you friendly and sensibly competed against other groups? Have you help them whenever they needed support or inspiration to get unstuck or optimize their structure?
6. Name two values that you will highlight about working with your group:
7. Name two values which you will highlights about sharing knowledge, opinions and ideas between groups:

B. Annex II. Tables for session's assessment

a) Specific tables

i. Self-assessment: My structure checklist

<table>
<tr><td colspan="4">MY STRUCTURE CHECKLIST</td></tr>
<tr><td colspan="2">Name of the group:</td><td>Yes</td><td>Not yet</td></tr>
<tr><td colspan="2">1. It stands</td><td></td><td></td></tr>
<tr><td colspan="2">2. It can move</td><td></td><td></td></tr>
<tr><td colspan="2">3. It has a clear function.</td><td></td><td></td></tr>
<tr><td colspan="2">4. It is the best at the function we propose</td><td></td><td></td></tr>
<tr><td colspan="2">5. We have used the proper materials for our structure to be the best at the function we propose.</td><td></td><td></td></tr>
<tr><td rowspan="3">6. I can contextualise my structure with the human body.</td><td>Bones</td><td></td><td></td></tr>
<tr><td>Muscles</td><td></td><td></td></tr>
<tr><td>Elastic elements</td><td></td><td></td></tr>
</table>

ii. Peer-assessment grid for structure defence.

PEER-ASSESSMENT GRID FOR STRUCTURE DEFENCE					
Which group assess?:		How to assess: They got it / They nearly got it / They still need to work on it			
Assessment criteria (Knowledge formulations + cooperation and collaboration)		**G1**	**G2**	**G3**	**G4**
Their structure can **stand**					
Their structure can **move**					
Their structure is **the best at the function they propose.**					
They have use the **proper materials** for their structure **to be the best at the function they propose.**					
They have **contextualised** their structure with the human frame	**Bones**				
	Muscles				
	Elastic elements				
Every member of the group **takes part in the defence**					
They **behave as a group.** They **respect** everyone's opinions, even in difficult moments.					
The group has **collaborated and cooperated** when it comes to deal with difficulties during the creation process.					
There has been **cross talk and collaboration between your group and this group** during the creation process.					
What is the **best thing they have done**? G1:... G2:...					

G3:..   G4:..
WRITE **AT LEAST TWO** SUGGESTIONS FOR I**MPROVEMENT**:   1. S*tructure creation:*   G1:..   G2:..   G3:..   G4:..   2. G*roup work:*   G1:..   G2:..   G3:..   G4:..

iii. Teacher's assessment grid for structure defence

TEACHER'S ASSESSMENT GRID FOR STRUCTURE DEFENCE		
Assessment criteria		
Level 3	*Level 2*	*Level 1*
Their structure **firmly stands**	Their structure *can stand*	Their structure *weakly stands*/*does not stand*
Their structure can clearly **move**	Their structure can move but it need to be forced by them (rigid movements)	Their structure cannot move
Their structure is **the best the function they propose.**	Their structure fulfils the function they propose.	Their structure does not fulfil the function they propose/ they do not propose any function for the structure.
They have used the **proper materials** for their structure and they are appropriately placed	They have used the proper materials for their structure but one of them is not appropriately placed/they have not used it.	They have not used the proper materials for their structure/two or three of them are not appropriately placed.
They properly **formulate** sentences which clearly show and summarise what they have learn after **each lesson.**	They formulate sentences that show some of the knowledge formulations they should acquire. They do not miss more than three.	They formulate sentences that show acquisition of some knowledge formulations but they skip most of them/ incorrectly formulate them
They **contextualise** their structure with the human frame regarding **bones, muscles** and **elastic elements**.	They contextualise their structure with the human frame but are mistaken with one tissue	They do not contextualise their structure with the human frame or are mistaken with two or three tissues.
Every member of the group **takes part in the defence.**	Every member takes part in the defence but some if them contribute more than others.	Not every one takes part in the defence/some contribute undoubtedly more than others

Group members have **negotiated and support each other** to overcome difficulties and get unstuck during the creation process.	Group members have sometimes **negotiated and support each other** to overcome difficulties and get unstuck during the creation process.	Group members have not **negotiated and support each other** to overcome difficulties and get unstuck during the creation process.
Cross-talk and collaboration has continuously taken place **between the group and the rest of groups** during the creation process (friendly competence).	**Cross-talk and collaboration** has sometimes taken place **between the group and the rest of groups** during the creation process (friendly competence).	**Cross-talk and collaboration** has not taken place **between the group and the rest of groups** during the creation process (friendly competence).
Collaboration, cooperation and sharism have clearly benefited and allowed them to successfully meet the lesson's objective.	Collaboration, cooperation and sharism have sometimes benefited and allowed them to successfully meet the lesson's objective.	Collaboration, cooperation and sharism have not benefited and allowed them to successfully meet the lesson's objective.
Autonomy, initiative. Degree of "interference" from the **teacher required**. They actively seek out materials and tools, do not give up taking challenges and show courage and take risks.	**Autonomy, initiative.** Degree of "interference" from the **teacher required**. They seek out materials and tools and make great effort not to give op challenges but sometimes they do and, in some occasions, they show courage and take risks.	**Autonomy, initiative.** Degree of "interference" from the **teacher required**.They neither seek out materials and tools nor take challenges. They do not show courage .
* *Level 3* → High Average (HA) * *Level 2* → Medium Average (MA) * *Level 1* → Low Average (LA)		

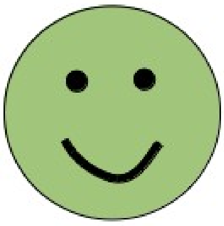
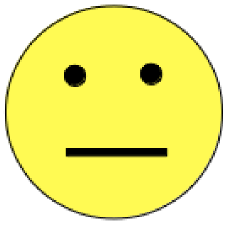
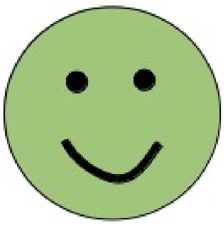
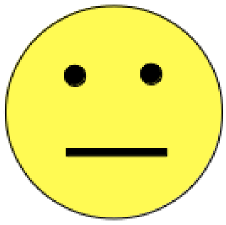
iv. Knowledge formulations assessment grid

KNOWLEDGE FORMULATIONS ASSESSMENT GRID Lesson 2: *Vertebrates. Bones, muscles and elastic elements*		
Level 3	*Level 2*	*Level 1*
Perfectly understands and identifies the function of three materials provided.	Understands and identifies the function of 2/3 of the materials provided.	Understands and identifies the function of 1/3 of the materials provided.
Perfectly understands and identifies the properties of the materials provided.	Understands and identifies the properties of 2/3 materials provided	Understands and identifies the properties of 1/3 or none of the materials provided.
Makes use of the three materials provided taking their functions and properties into account.	Makes use of the three materials provided but forgets to take into account the functions and properties of one of them.	Makes use of the three materials provided but forgets to take into account the functions and properties of at least two of them or does not make use of the three materials.
Perfectly understands and identifies the function of bones, muscles and tendons/ligaments.	Understands and identifies the function of 2/3 tissues (bones, muscles and tendons/ligaments). Has difficulty with one of them.	Understands and identifies the function of 1/3 tissues (bones, muscles and tendons/ligaments) or none of them. Has great difficulty identifying functions.
Perfectly understands and identifies the properties of bones, muscles and tendons/ligaments.	Understands and identifies the properties of 2/3 tissues. Has difficulty with the properties of one of them.	Understands and identifies the properties of 1/3 tissues or none of them. Has difficulty with the properties of two/three of them.
Can explain/verbalize and physically represent the relation between muscles, bones and tendons/ligaments when it	Can explain/verbalize the relation between muscles, bones and tendons/ligaments when it comes to provide support	Cannot explain/verbalize the relation between muscles, bones and tendons/ligaments when it comes to provide support

comes to provide support and flexibility to the human body.	and flexibility to the human body. Struggles to physically represent it or has some mistakes that do not lead to misunderstanding.	and flexibility to the human body and/or cannot represent their relation at all.
Is able to relate the functions and physical properties of three materials to the function and physical properties of our bones, muscles and tendons/ligaments.	Is able to relate 2/3 functions and physical properties of three materials to the function and physical properties of our bones, muscles and tendons/ligaments.	Is able to relate 1/3 or none of the functions and physical properties of three materials to the function and physical properties of our bones, muscles and tendons/ligaments.
Can physically represent the relation between our bones, muscles and tendons/ligaments using three materials provided. Is able to give an explanation linking the human body to the creation.	Can physically represent the relation between our bones, muscles and tendons/ligaments using three materials provided, but struggles to give an explanation linking the human body to the creation/ Struggles to physically represent the relation between our bones, muscles and tendons/ligaments using three materials provided, but can give an explanation linking the human body to the creation.	Cannot physically represent the relation between our bones, muscles and tendons/ligaments using three materials provided, or/and cannot give an explanation linking the human body to the creation
* *Level 3* → High Average (HA) * *Level 2* → Medium Average (MA) * *Level 1* → Low Average (LA)		

b) General tables

i. Self-assessment grid: How was my work today?

How was my work today?			
Knowledge formulations (K)			
Collaboration cooperation (C)			
	I am there	I am nearly there	I am not sure yet

ii. Teacher's register grid: How was my work today?

TEACHER'S REGISTER: How was my work today?												
Group	Pupil	Session 1		Session 2		Session 3		Session 4		Observations		
		K	C	K	C	K	C	K	C	K	C	Notes:
1												
2												
3												
4												

I am there → K / C (green colour)

I am nearly there → K / C (yellow colour)

I am not sure yet → K / C (red colour)

Absent → *

Knowledge Formulations (K)

Collaboration and cooperation (C)

C. Annex III. Tables for general assessment

b. Results Observation Grid for Methodological Principles and Proposal Adaptation to School

RESULTS/OBSERVATION REGISTER : METHODOLOGICAL PRINCIPLES AND PROPOSAL DIDACTIC DESIGN							
		PRINCIPLES	Session 1	Session 2	Session 3	Session 4	Session 5
ASPECTS	a) Deeper learning	Understanding, representation and application of one's ideas					
	b) Learning by doing	Motivation and engagement					
		Materials and resources provided					
		Multiple pathways allowed					
		Encourage pupils to complexify their thinking					
	c) Social environment	Enables Inspiration (past projects)					
		Enables cross-talk and collaboration					
		Enables individual initiative and autonomy					
		Enables cross-pollination of ideas					
	d) Facilitation	Is welcoming and sparks interest					
		Focuses on individual paths of understanding					
		Strengthens understanding (reflective conversation)					
ADAPTATION (pupils / school)		Session's distribution					
		Timing					
		Learning Objective/Knowledge formulations					

D. Annex IV. Results of the implementation.

a) Session's development tables

i. Material's exploration grid

<table>
<tr><td colspan="4">MATERIALS' EXPLORATION GRID</td></tr>
<tr><td>Materials</td><td>Use</td><td>Function</td><td>Physical Properties</td></tr>
<tr><td rowspan="4">Carton</td><td>(1) Buildings
As support</td><td rowspan="4">Support</td><td rowspan="4">Rigid

Hard

You cannot pull them</td></tr>
<tr><td>(2) Body, rocks, nose, legs, bridge structure.</td></tr>
<tr><td>(3) Body, rocks, nose, legs, bridge structure</td></tr>
<tr><td>(4) face, bridge structure, guy</td></tr>
<tr><td rowspan="4">Elastic band</td><td>(1) Sea, cape, paint, skin</td><td rowspan="4">Flexibility (question about properties needed to conclude the function)</td><td rowspan="4">Flexible

Stretchy

You can pull them</td></tr>
<tr><td>(2) Moat</td></tr>
<tr><td>(3) Sea, cape, paint, skin</td></tr>
<tr><td>(4) Water, smily face, crown, slingshot</td></tr>
<tr><td rowspan="4">Woollen thread</td><td>(1) River, top buildings, join things</td><td rowspan="4">Join</td><td rowspan="4">Stiff

Not flexible</td></tr>
<tr><td>(2) to put carton together, to group things together</td></tr>
<tr><td>(3) Strings of a bridge, to join the wings of a plain, hair, electric fence</td></tr>
<tr><td>(4) Hair, handcuffs, cheeks, to join carton for creating a bridge</td></tr>
<tr><td colspan="4">(1) The Clever Clogs
(2) Science Kids
(3) Brain Waves
(4) Super Secret Scientists</td></tr>
</table>

c) General assessment tables

i. Self-assessment register: How was my work today?

SELF-ASSESSMENT REGISTER: How was my work today?												
Group	Pupil	Session 1		Session 2		Session 3		Session 4		Observations		
		K	C	K	C	K	C	K	C			Notes:
1. Brain Waves	*Pupil A*	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
	Pupil B	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
	Pupil C	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
	Pupil D	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
2. Science Kids	*Pupil E*	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
	Pupil F	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
	Pupil G	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
	Pupil H	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
3. The Clever Clogs	*Pupil I*	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
	Pupil J	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
	Pupil K	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
	Pupil L	*K*	*C*	*K*	*C*	*K*	*C*	*	*			
4. Super Secret Scientists	*Pupil M*	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
	Pupil N	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
	Pupil O	*K*	*C*	*K*	*C*	*K*	*C*	*	*			
	Pupil P	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			
	Pupil Q	*K*	*C*	*K*	*C*	*K*	*C*	*K*	*C*			

- I am there → K / C (green colour)
- I am nearly there → K / C (yellow colour)
- I am not sure yet → K / C (red colour)
- If the pupil considers being in the middle of two stages → Combination of their colours → Green and yellow or yellow and red.
- Absent → *
- Knowledge Formulations (K)
- Collaboration and cooperation (C)

e) Final outcomes

Brain Waves!

by: Maithili, Marco, Siya and Casper.

Steps

Creation Process

First we thought of making a city park. On the following day, we wanted to do a water park. We made a water stage with animals, a castle, a swimming pool, grass, a climbing and the sign of the cross with where things are, we made a rock climbing on water. There is a waterfall that you can slide down. We hope you learnt something from us.

Our statements

1) Carton
I can use carton for buildings, rocks, a body and structure. Its function is support. Its physical property is rigid and hard.
Elastic Bands
I can use Elastic bands for the sea, the roof, pool, catapult and slingshot. Its function is flexibility. Its physical property is it is elastic.
Woollen Thread
I can use woollen thread for tight ropes, hair, zip wire. Its function is joining together. Its physical property is stiff.

2) The bones are like carton because they are stiff, rigid, hard and it gives the body support.
The muscles are like Elastic band, because they are bendy and they have got flexibility.
The tendons are like woollen thread because they join our muscles and bones together.

3) We used carton for buildings and the pool. We used the Elastic band for the pool and castle. We used woollen thread for flags and signs.

4) We used a lot of carton for the castle and our buildings. It gives support to them. We used elastic bands for flags for stretchiness. We used woollen thread to join our castle.

Group Work

We worked good in our group because we helped each other and if didn't agree, we mixed our ideas and made new creations. The elastic pieces and bands were harder than thought. We took the idea of grass from Super Secret Scientists. We would rather work in groups than on our own because working in groups makes everything more fun. It gives us brain waves.

Contextualization

We used wollen thread to join the towers and the climbing frame. We used the elastic bands to stretch the castle flag and make it flap. We used the cartons to support the castle and the climbing frame and the sign and our buildings. Tendons join our muscles that bring flexibility to our body and our bones that support our body, like woollen thread. Bones support our body so we don't fall down, Muscles bring flexibility to our body to help us move.

The Clever Clogs

by: Matthew, Angelina, Joe and Ben

Our Statements

1st Day:
I can use cartons for rocks and buildings. Carton's function is support and its physical properties are rigid, stiff and hard.
I can use elastic band for skin and water. Its function is flexible and stretchy. Its physical property is you can stretch it.
The woollen thread is used for joining things together. Its physical properties are it is stiff, not flexible.
2nd Day:
Our bones are like carton because they are hard and rigid, they give us support. Our muscles are like elastic because the are bendy, they give us flexibility. Our joints are like string because they join together with the joints, they give us flexibility and movement.
3rd Day:
We have used elastic band for chocolate spread, carton for the marshmallow and machines and woollen thread for joining things.
4th Day:
We have used elastic band for the chocolate. We have used carton for our marshmallows. We have used string for the wire.

Our structure

Our Creation Process

STEPS!

1. At first we used the carton for the marshmallow on a stick.
2. We took the elastic bands and the string to make and detach the carton to make the chocolate.
3. We took another two cartons for doors to make our factory a welcoming factory.
4. We used the woollen thread for joining other materials together and make a wire of chocolate.
5. We started by getting a carton stick and stick the carton tube through the stick to make a marshmallow stick. So we put the marshmallow stick on the chocolate wire to make it chocolatey. The elastic band streched to make the coating of the marshmallow.

Collaboration and Cooperation

Our group/with other groups

Ben, Matthew, Angelina and Joe have been working together as a friendly group, no one has been left out. All of us have been giving ideas and helping the group. When we had a problem we fixed it by asking a person in the group. It has been better working in groups because we can share each others ideas to create things like our chocolate factory were we had a marshmallow machine, a chocolate wire.

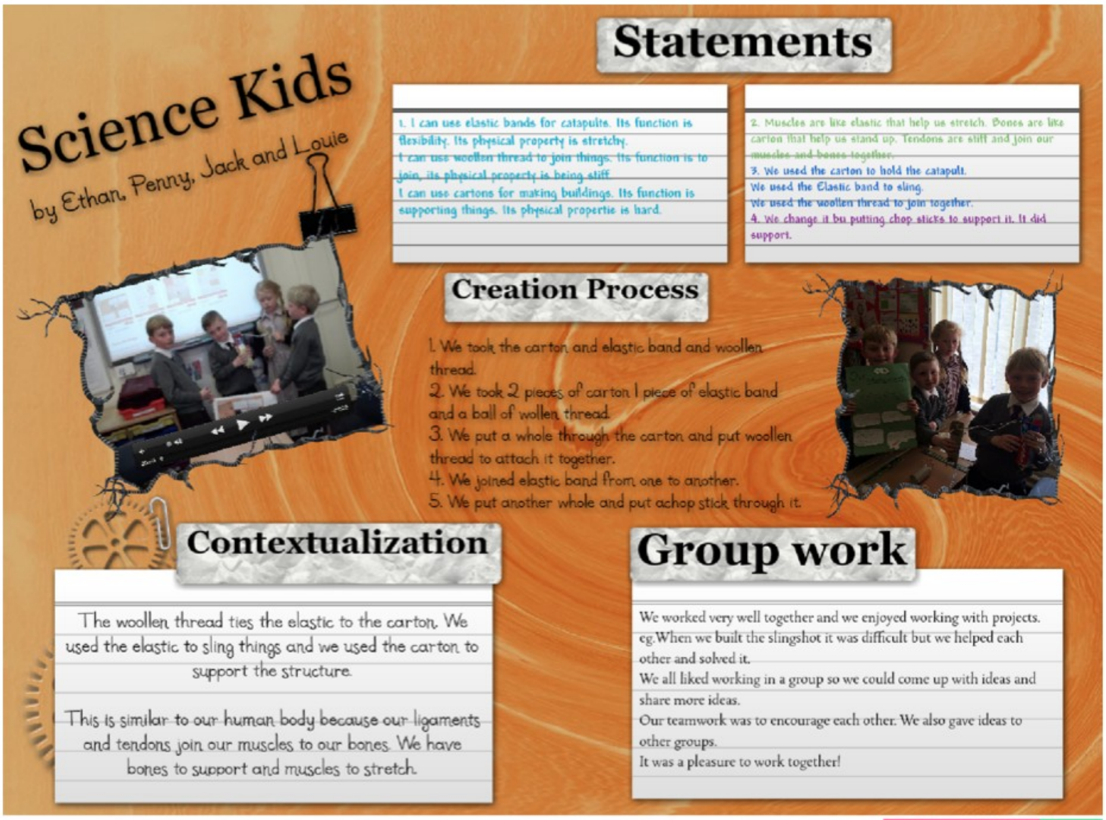
Contextualization

Our structure and the human body structure

We joined the tube and the marshmallows with the woollen thread. We used the woollen thread to make the flag to join the chocolate tube. Carton supports our fantastic chocolate factory.
This is like our bones support, muscles stretch and the tendons join.

Glog from Liverpool GB May 13 2015
by reyguembe

Glogster EDU
edu.glogster.com



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